



Effect of Live High – Train Low Altitude Training on Hemoglobin Mass and Sea Level Endurance Performance



Experiences with Swiss World Class Endurance Athletes

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Endurance Physiology Group, Section for Elite Sport



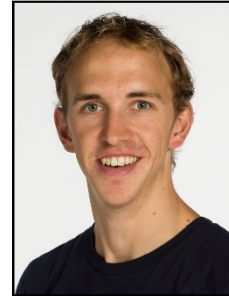
Anna Hauser,
MSc, 100%.
PhD Student



Thomas Steiner
PhD, 100%.
XC Skiing,
Triathlon



Thomas Maier ,
MSc ETH 100%.
MTB, Biathlon.



Severin Trösch,
MSc ETH, 100%.
Athletics,
XC Skiing,
Triathlon



Beat Müller
BSc EHSM,
DTLG,
60%. MTB,
Biathlon
Coach
Swiss Cycling.



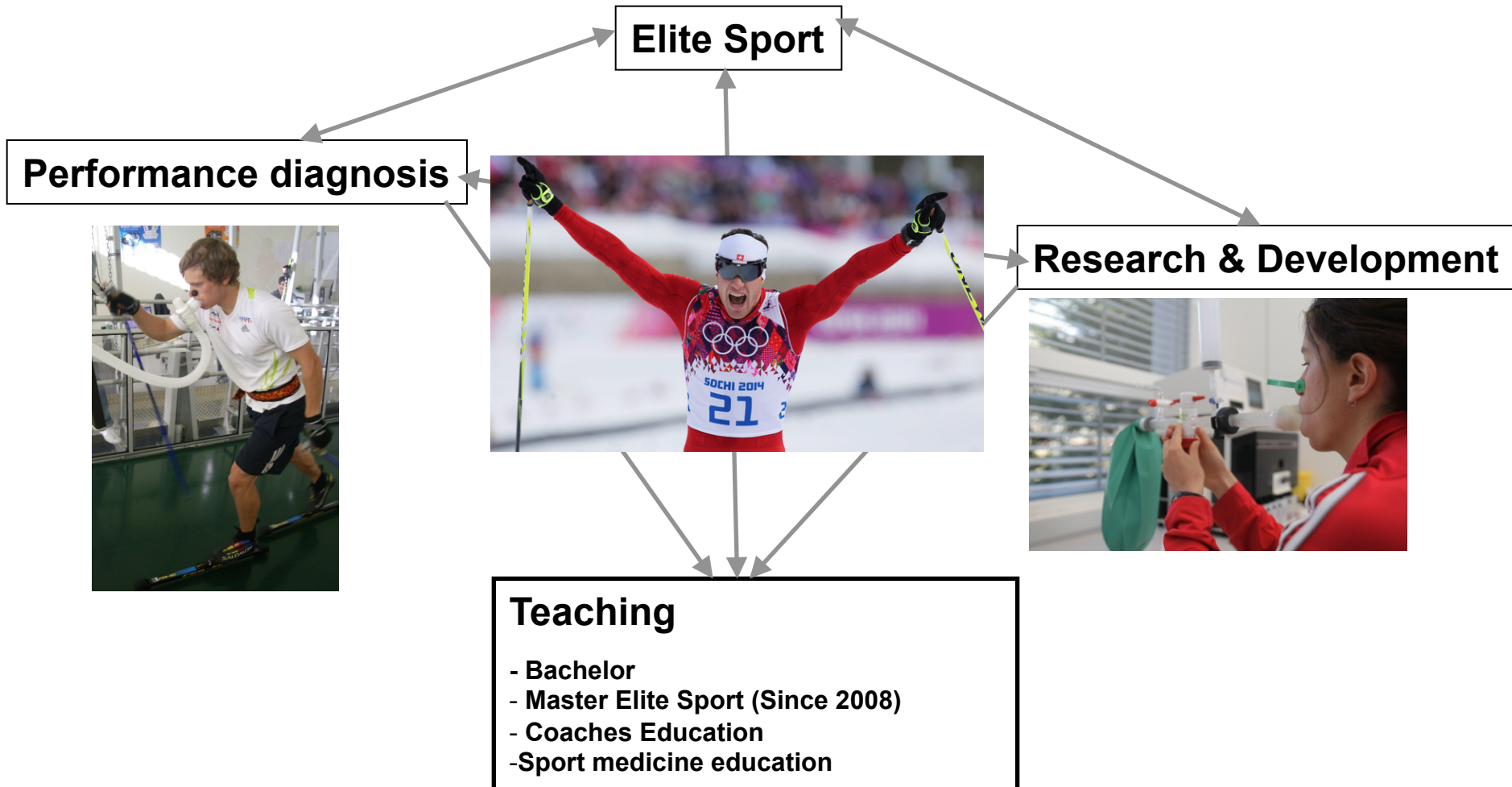
**Neu: Raphael
Faiss, PhD,**
100%.
Cycling.



Jon Peter Wehrin
PhD, 100%.
Head Group



=> Section for Elite Sport
(Collaboration with Swiss Olympic Association)



Contents:

- 1) Origin of Altitude Training: Live High – Train High**
- 2) Live High – Train Low Altitude Training: Effects on Hemoglobin Mass and Sea Level Performance**
- 3) Individual Hemoglobin Mass Responses**
- 4) Examples: Experiences with Swiss National Team Athletes**



1) Origin of Altitude Training: Live High – Train High



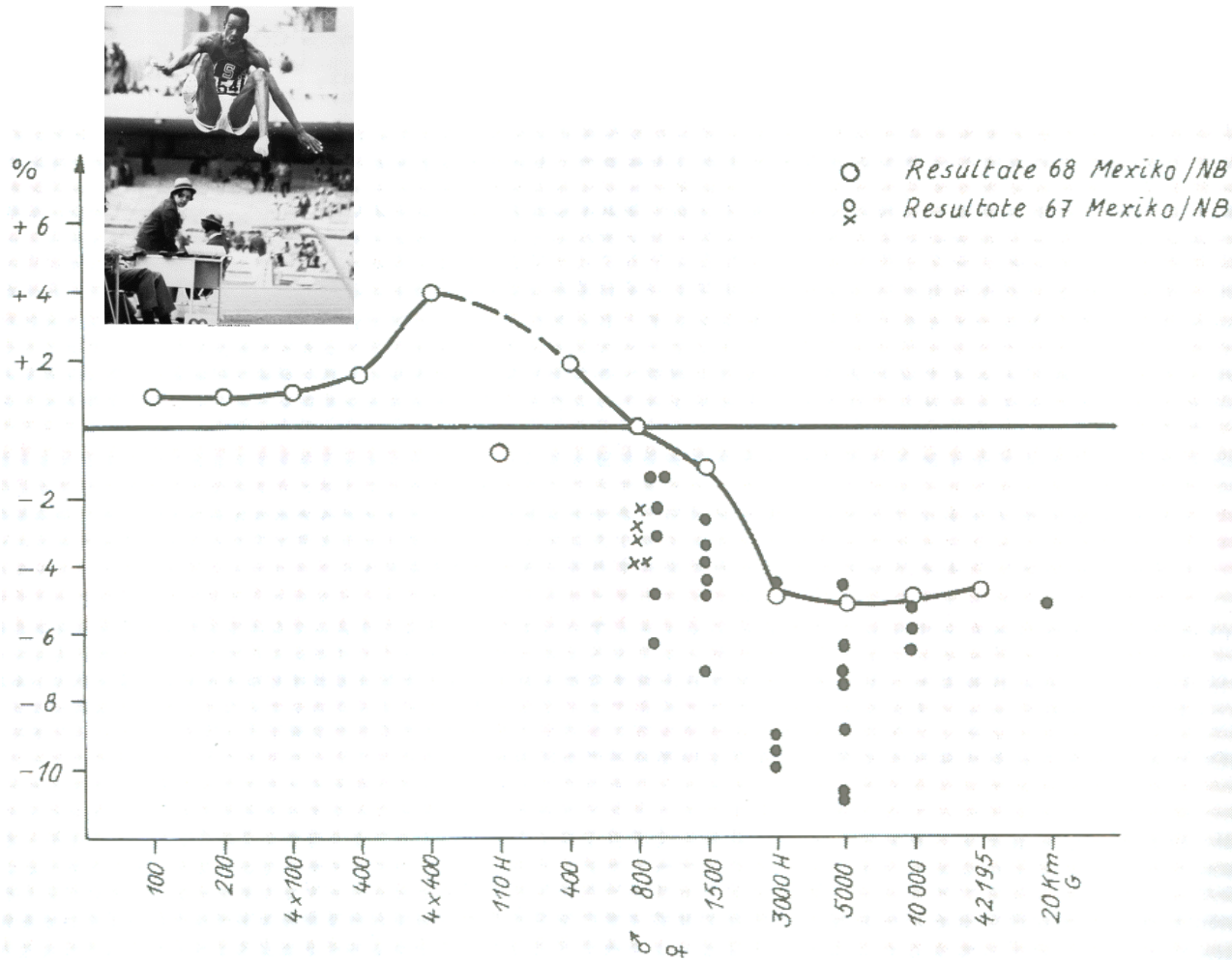


Olympic Games 1968 in Mexico City (Altitude 2300m)





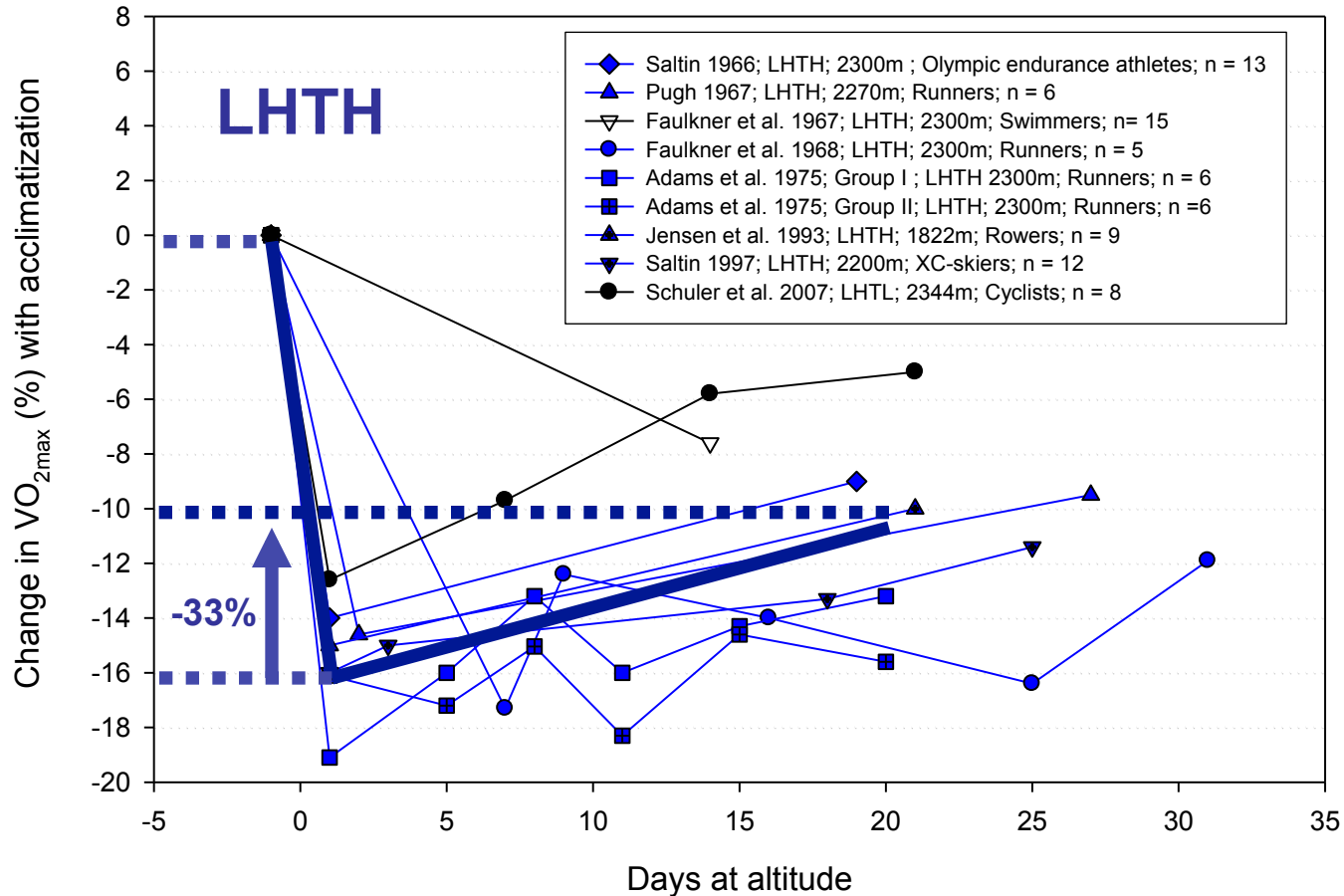
Results of the Olympic Games 1968 in Mexico City



Fuchs U, Reiss M. .Höhentraining – Das Erfolgskonzept der Ausdauersportarten. Philipka,, Münster 1990, Trainerbibliothek.



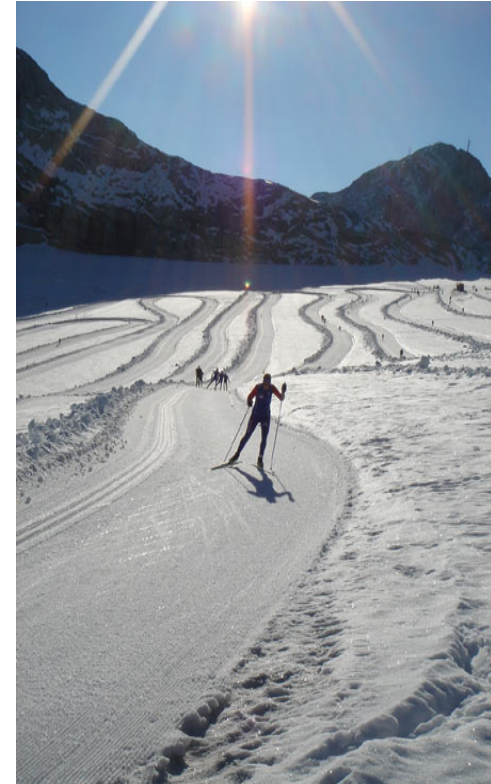
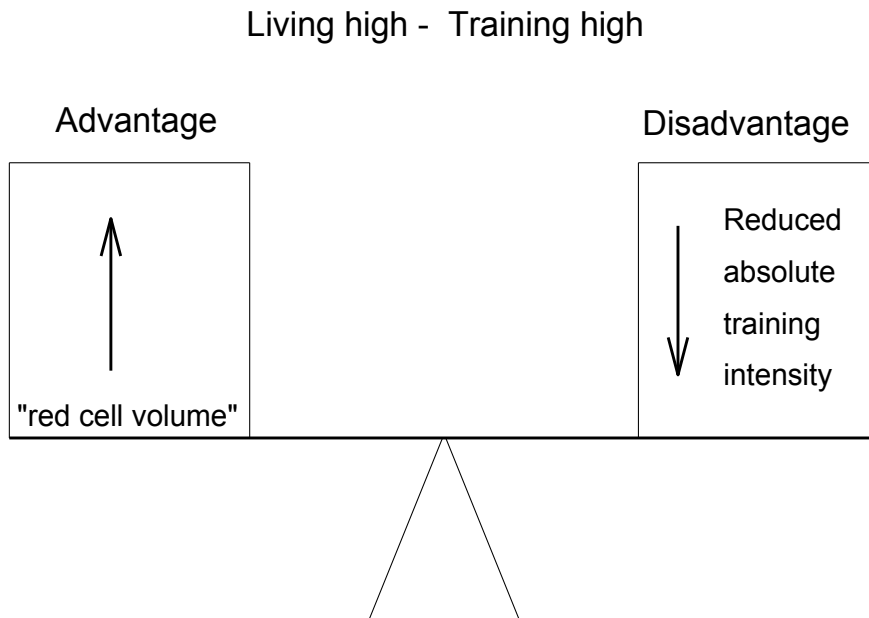
Preparing for Competitions at Altitude





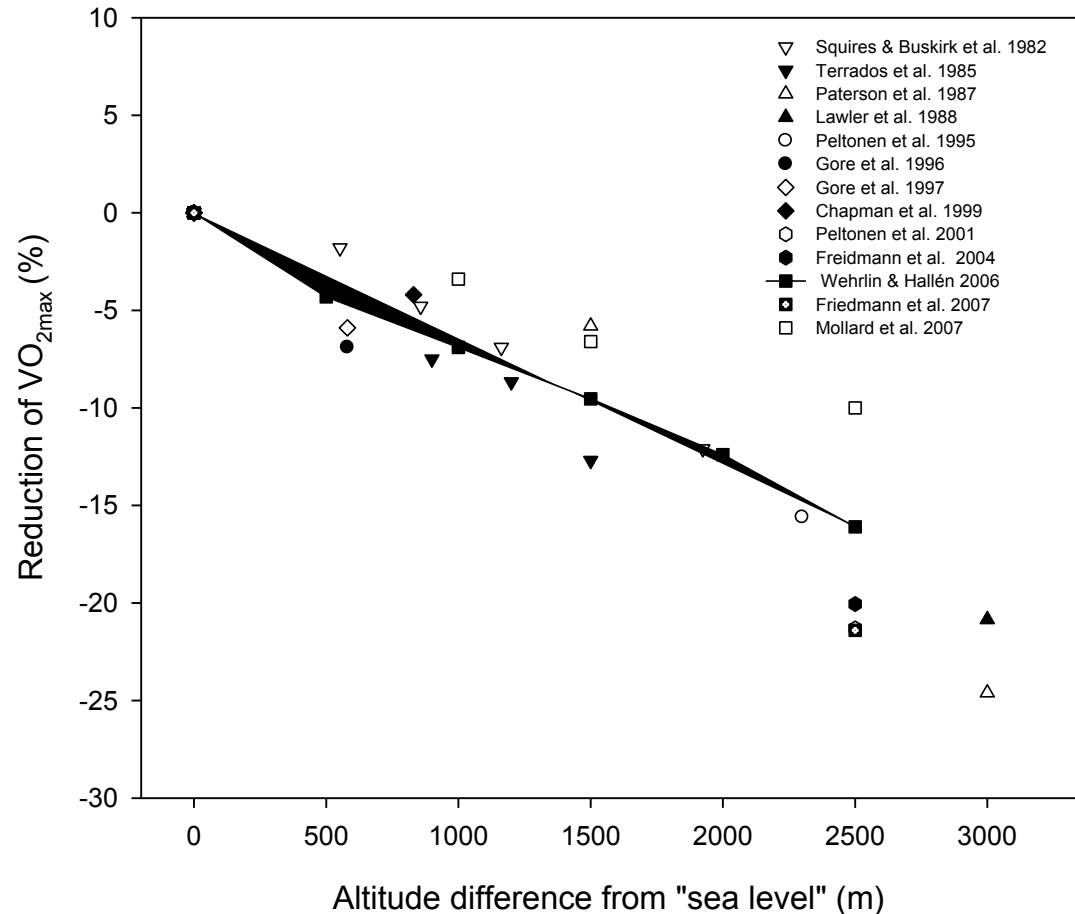
Live High – Train High

Preparing for Competitions at Sea Level





Reduced Absolute Training Intensity at Altitude



Wehrlin & Hallén, *Eur J Appl Physiol*, 2006

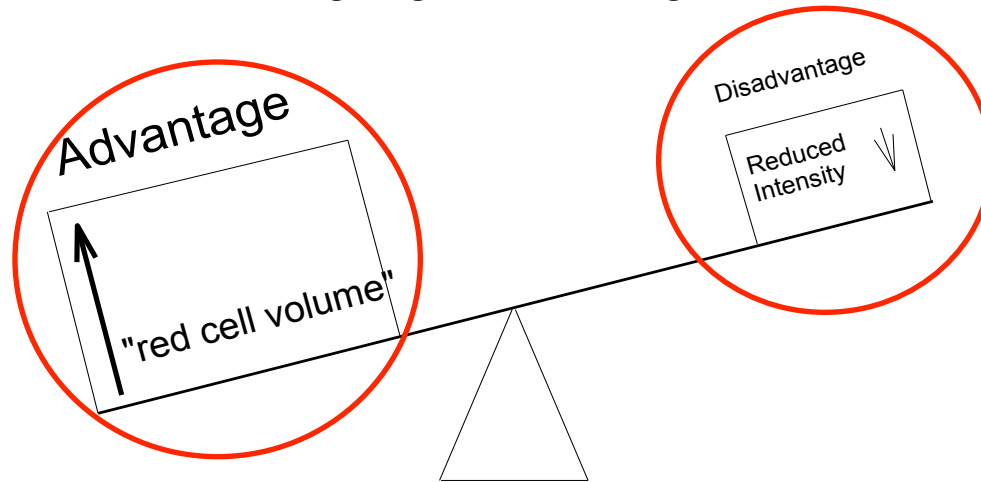
**2) Live High – Train Low Altitude Training:
Concept and Background Information**





Live High – Train Low

Preparing for Competitions at Sea Level



“Living high-training low”: effect of moderate-altitude acclimatization with low-altitude training on performance

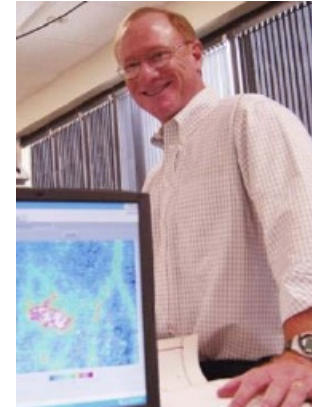
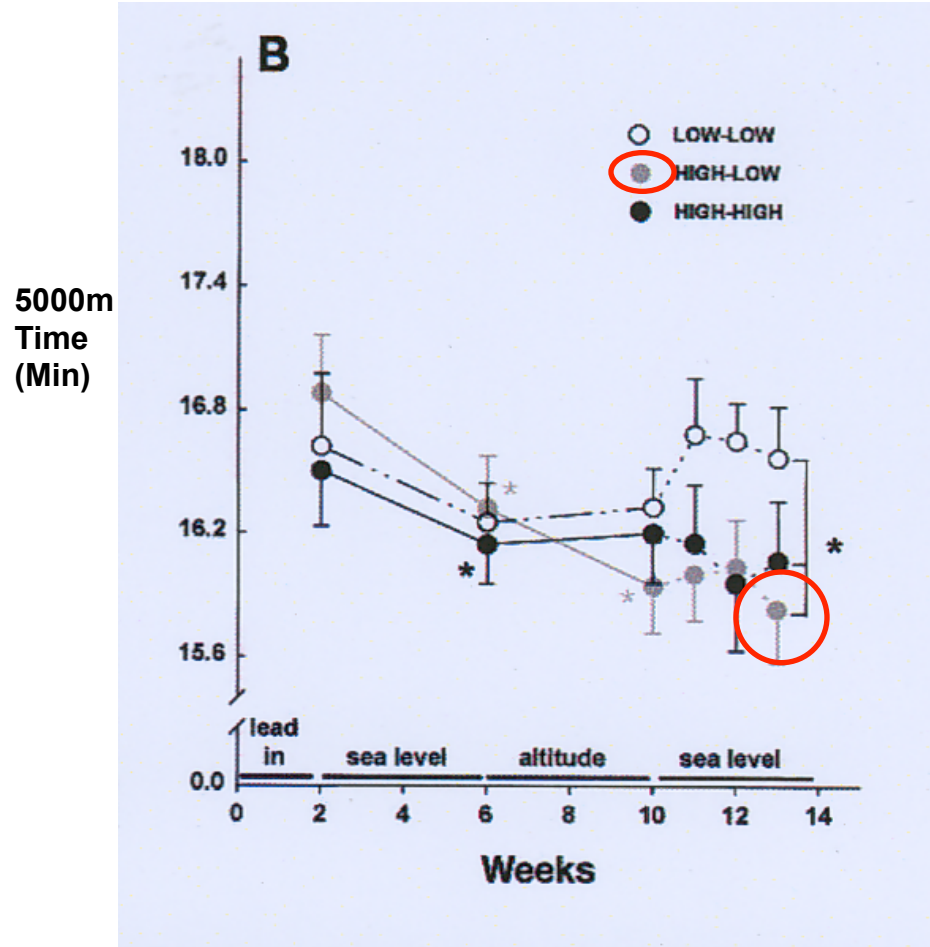
BENJAMIN D. LEVINE¹ AND JAMES STRAY-GUNDERSEN²
¹Institute for Exercise and Environmental Medicine, Presbyterian Hospital of Dallas 75231; and
²Baylor/The University of Texas Southwestern Sports Science Research Center,
The University of Texas Southwestern Medical Center, Dallas, Texas 75235

Levine & Stray-Gundersen, J Appl Physiol, 1997



Live High – Train Low

Preparing for Competitions at Sea Level



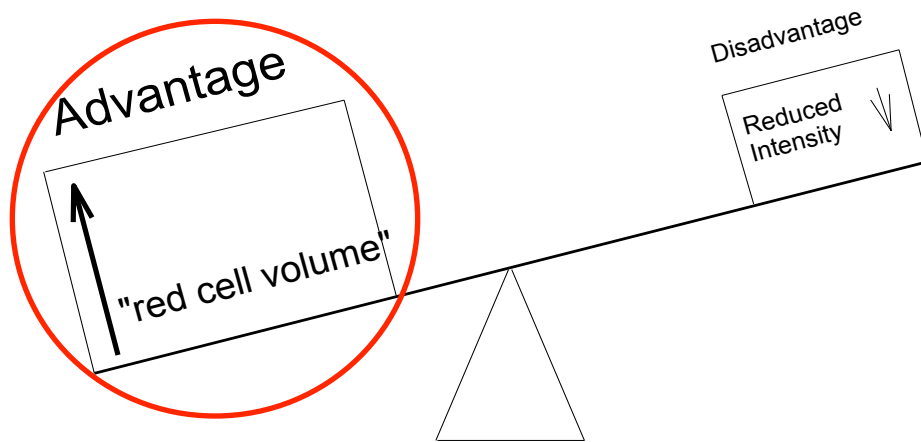
Levine & Stray-Gundersen, *J Appl Physiol*, 1997



Live High – Train Low

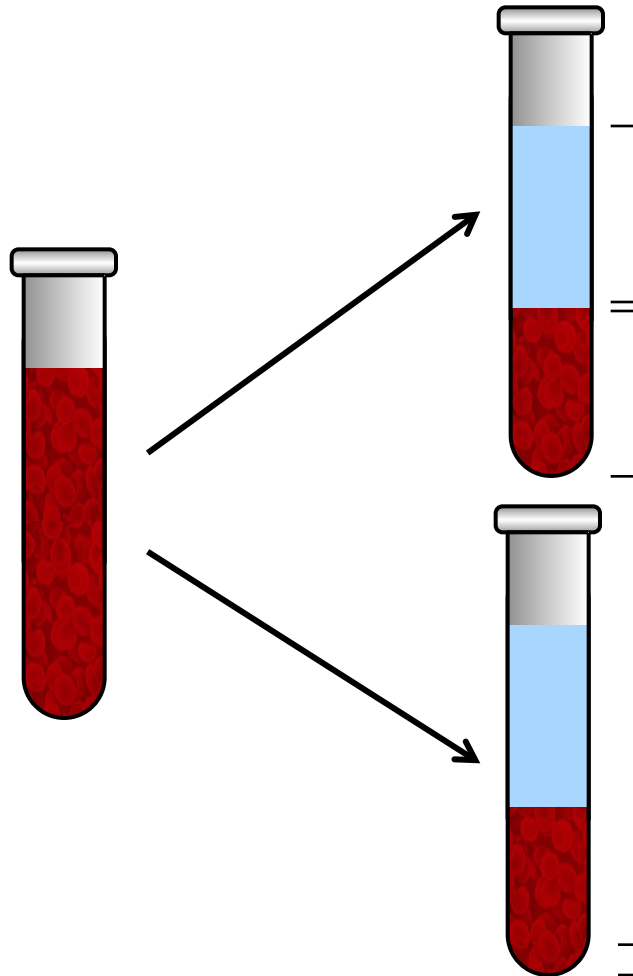
Preparing for Competitions at Sea Level

Living high - Training low





Blood – Concentration Measures



Hematocrit (Hct; %)

Percent red blood cells

Men ca. 45%

(Critical value men 50%)

Hemoglobin (Hb; g/dl)

Mean value ca. 15g/dl /

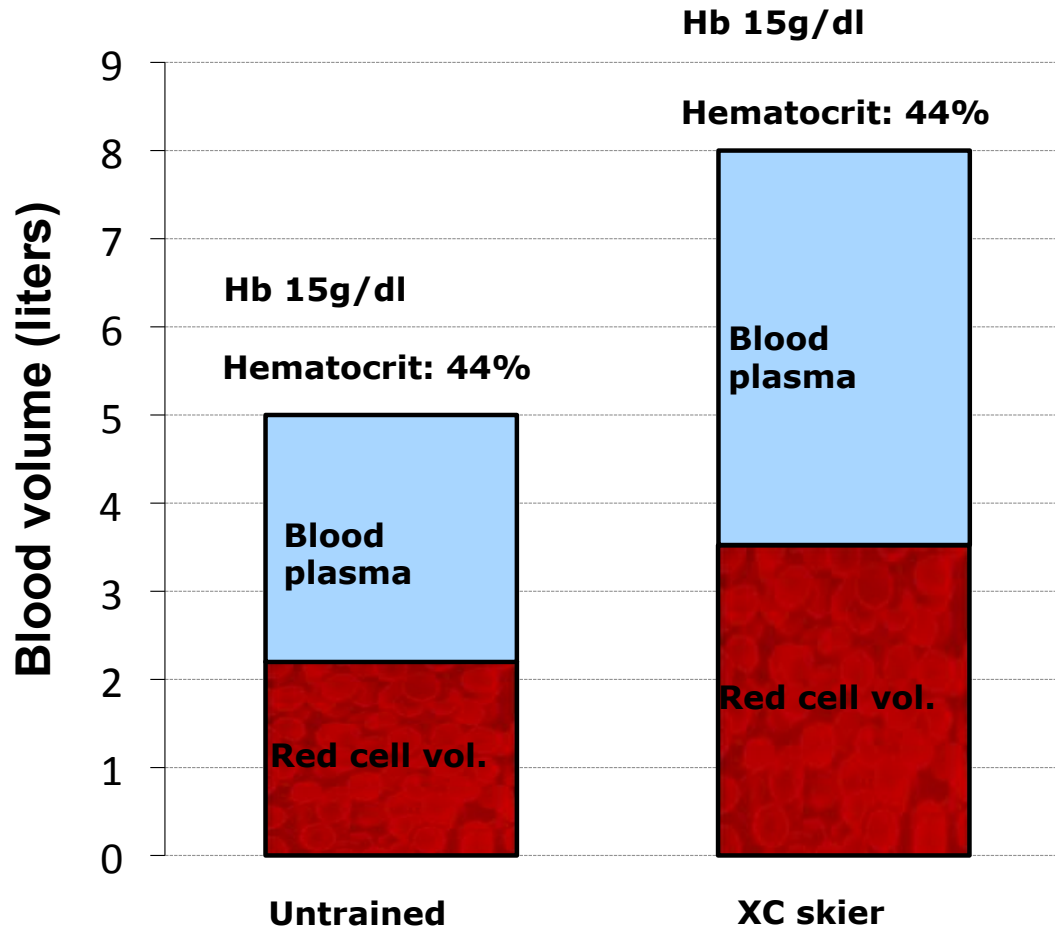
(critical value 17g/dl)

Red color in red blood cells, Binds the oxygen



Live High – Train Low

Blood

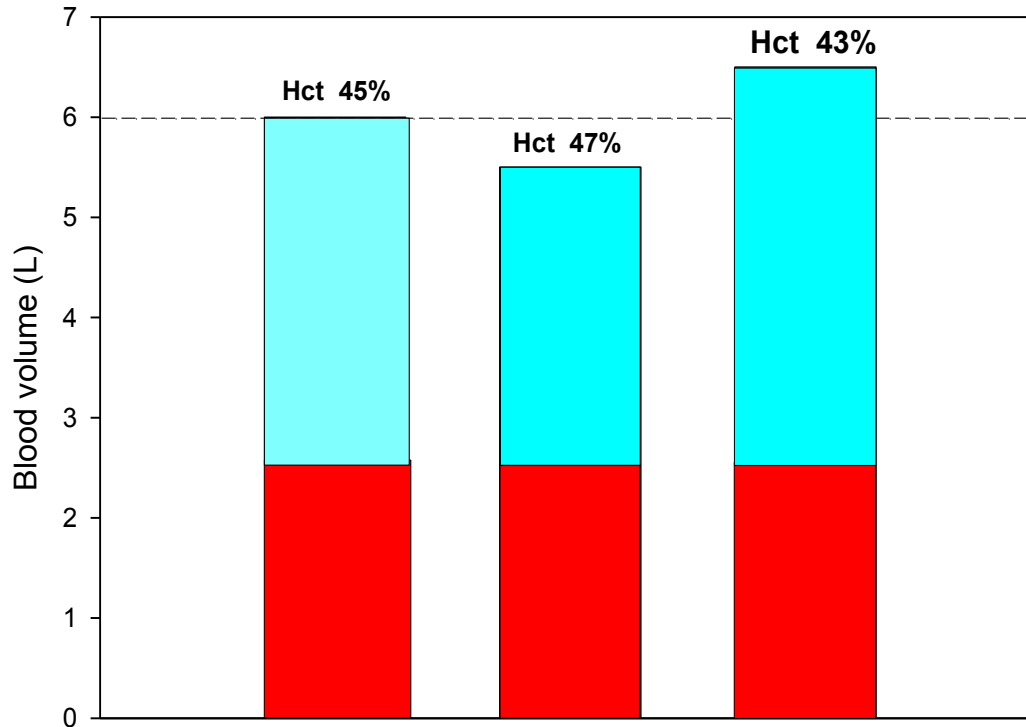


Problem: We do not know how the absolute values are!



Blood

Hb (g/dl) and Hct (%): Effects of changes in plasma volume



Important factors:

- Position: (horizontal = ↓ vs vertical = Hct ↑)
- Hydration status (low = Hct ↑; high ↓)
- Training (acute = Hct ↑; after = Hct ↓)
- Altitude: (acute = Hct ↑)
- Heat: (acute = Hct ↑; chronic ↓)



Live High – Train Low

Blood – Absolute values

**Blood volume:
8000 ml**



**Hemoglobin mass:
1256 g**



**Red cell volume:
3520 ml**

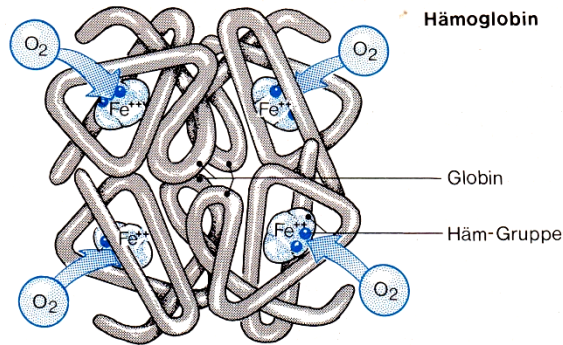


**Plasma volume:
4480 ml**

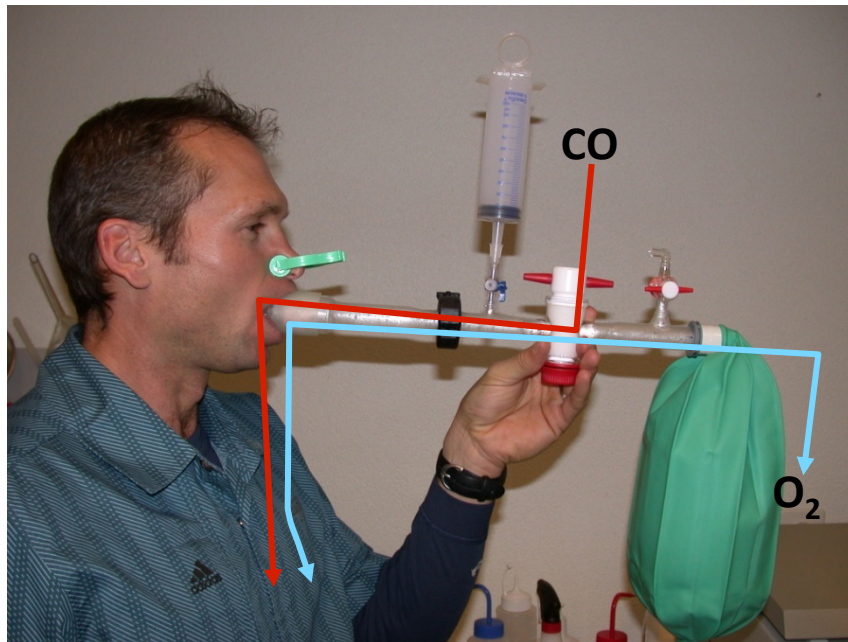




Blood



=> Total amount of hemoglobin in g



CO-rebreathing method (100 years):

- Revived by Fogh-Andersen et al. (1990) and Thomsen et al. (1991) and is now frequently used in Sports Science and Sports Medicine:

- “Optimized method” by Schmidt and Prommer (2005)

- with minor modifications (Prommer & Schmidt 2007)

Meta-Analysis about Error Measurement for blood volume parameters (Gore et al. 2005):

=> CO-rebreathing-method has the lowest error



Endurance sport: VO_{2max} - Possible limiting factors



Lung diffusion capacity

Heart capacity

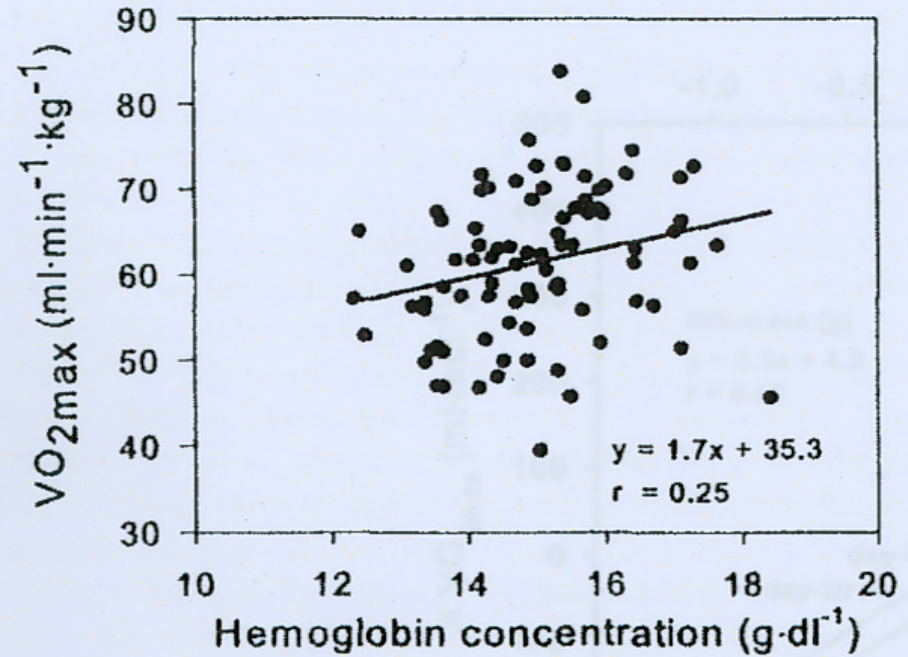
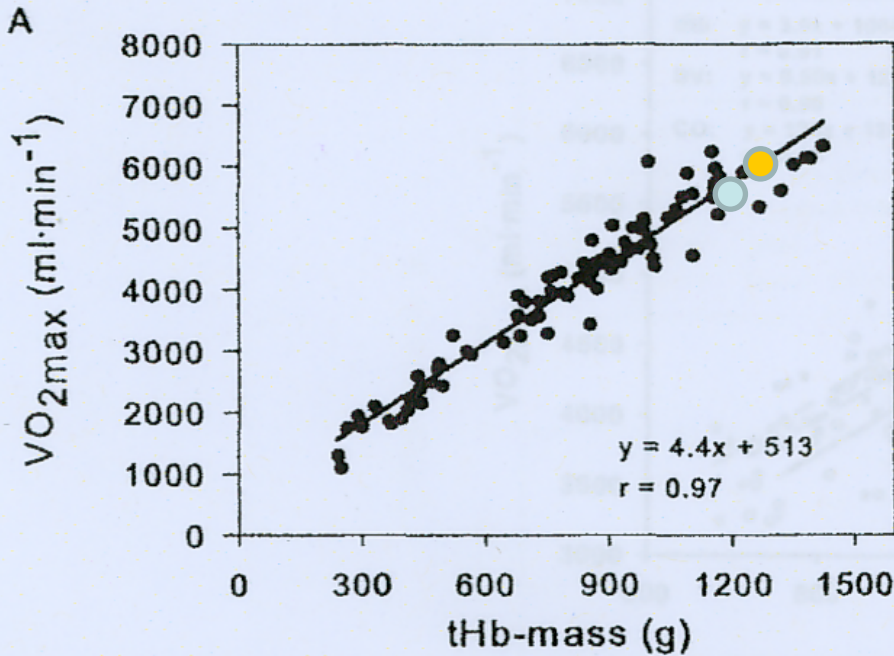
Oxygen transport capacity

Muscle capacity

Bassett DR and Howley ET. Limiting factors for maximum oxygen uptake and determinants of endurance performance. Med Sci Sports Exerc. 2000; 32: 70-84.



Blood



Schmidt & Prommer *Exerc Sport Sci Rev*, 2010



Endurance Sport: Blood Doping

....can move you from 30th place to the podium...



Stray-Gundersen J, Videman T, Penttilä L, Lereim I; Abnormal hematologic profiles in elite cross-country Skiers: blood doping or? Clin J Sports Med, 2003, 132-7



Importance of the hemoglobin mass: Blood doping

Switzerland

Tages-Anzeiger SPORT

Gedopter Thomas Frei erklärt, wie er die Kontrolleure jeweils täuschte

Von Emil Bachofner Aktualisiert um 11:23 Uhr

An einer Pressekonferenz in Olten nahm BMC-Fahrer Thomas Frei zu der positiven Dopingprobe Stellung, wegen der er vom Team vergangenen Mittwoch aus der Trentino-Rundfahrt genommen worden war.



Gesätzig: Thomas Frei erklärt, wie er nach einer Epo-Spritze mit einem Liter Wasser die Spuren verwischen konnte. Bild: Keystone

Spain

ELITODOPING

Neue Testergebnisse bringen Contador in Erklärungsnot

Unermüdlich beteuert der Tour-de-France-Sieger Contador seine Unschuld. Doch er wird neu belastet. Auch seine Schutzmacht, der Weltverband UCI, steht am Pranger.

© Pedro Armentia/AFPG/Getty Images



Der dreimalige Tour-Sieger Alberto Contador

USA



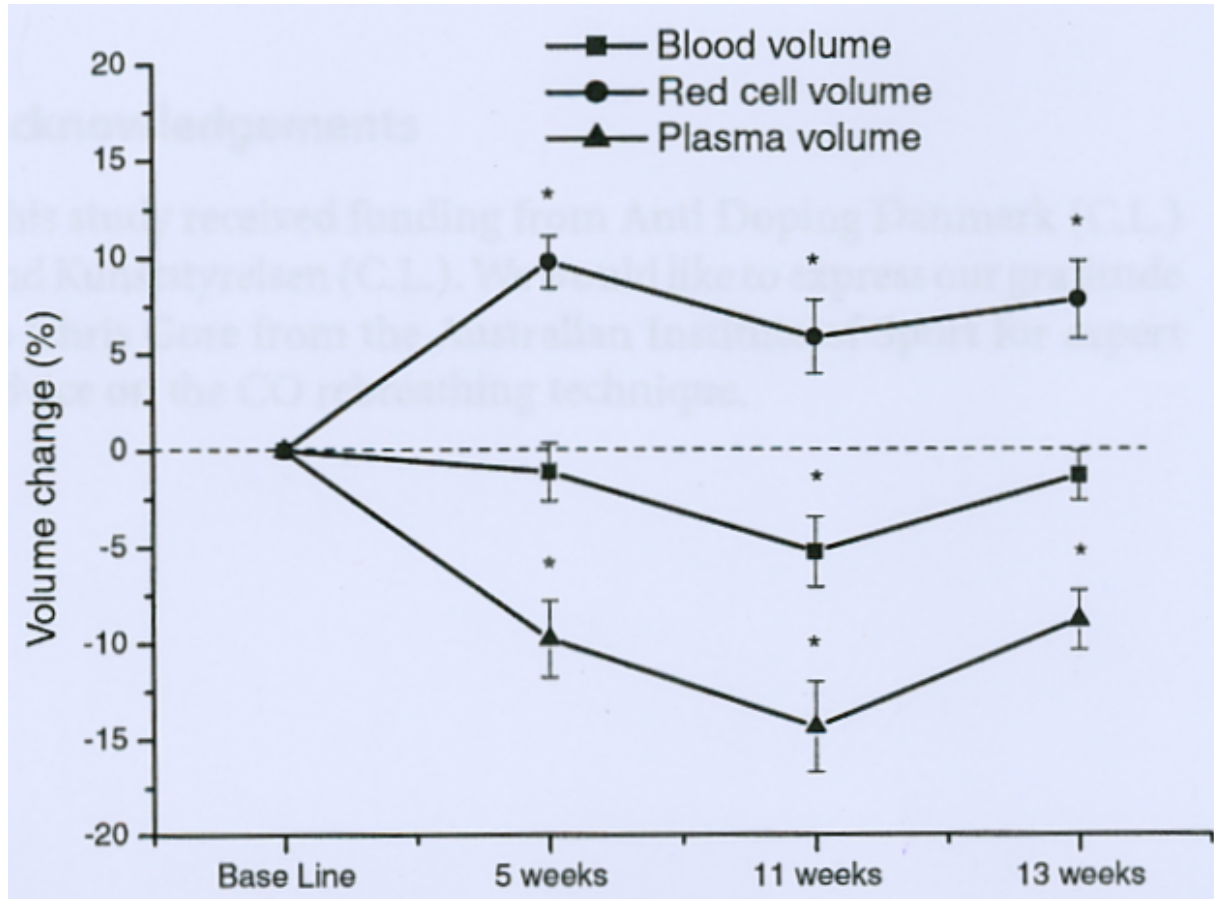
Denmark



.....etc.



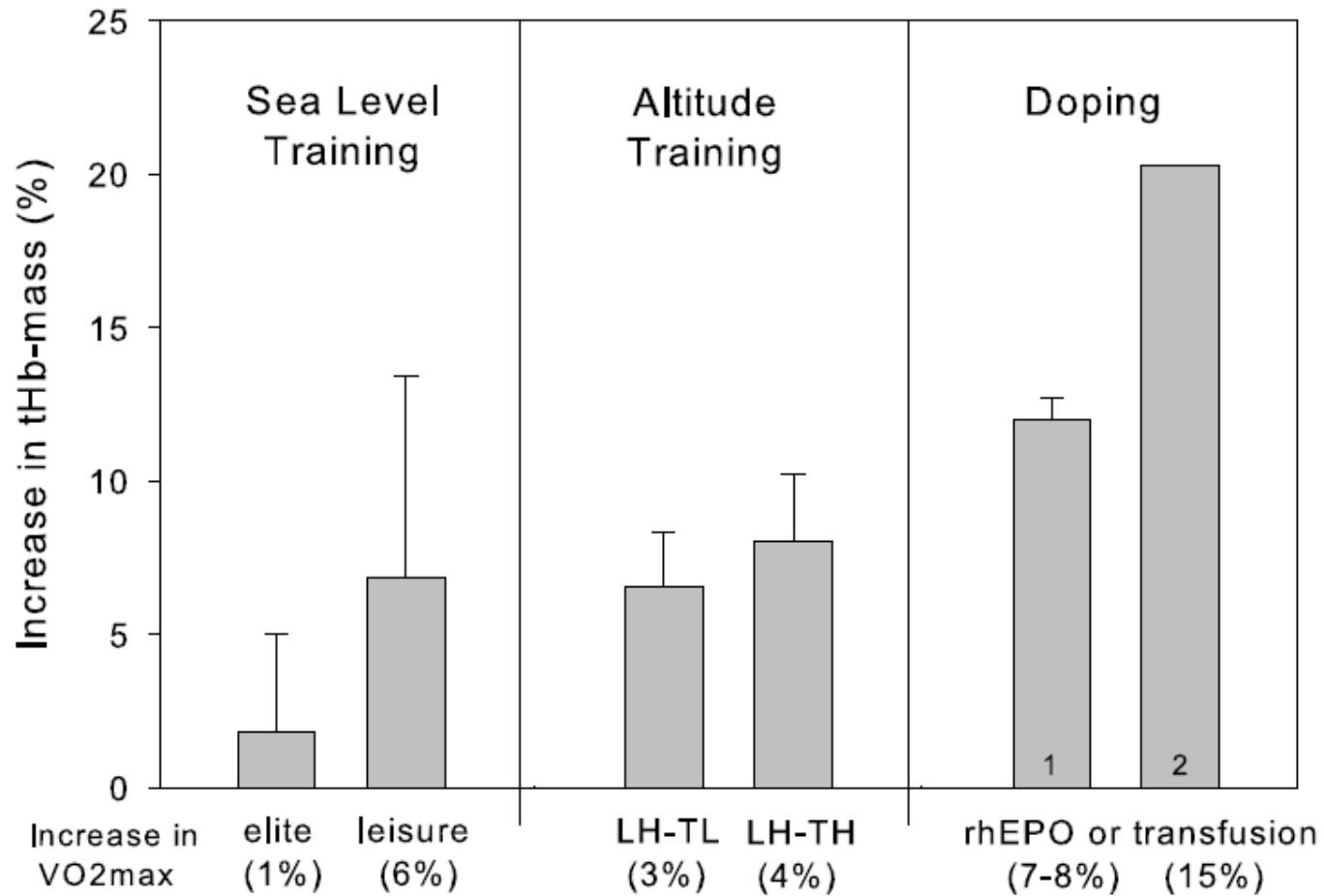
Increase in Red Cell Volume (Hemoglobin mass) with rhEPO Doping



Lundby et al., *J Physiol*, 2007



Blood



Schmidt & Prommer *Exerc Sport Sci Rev*, 2010

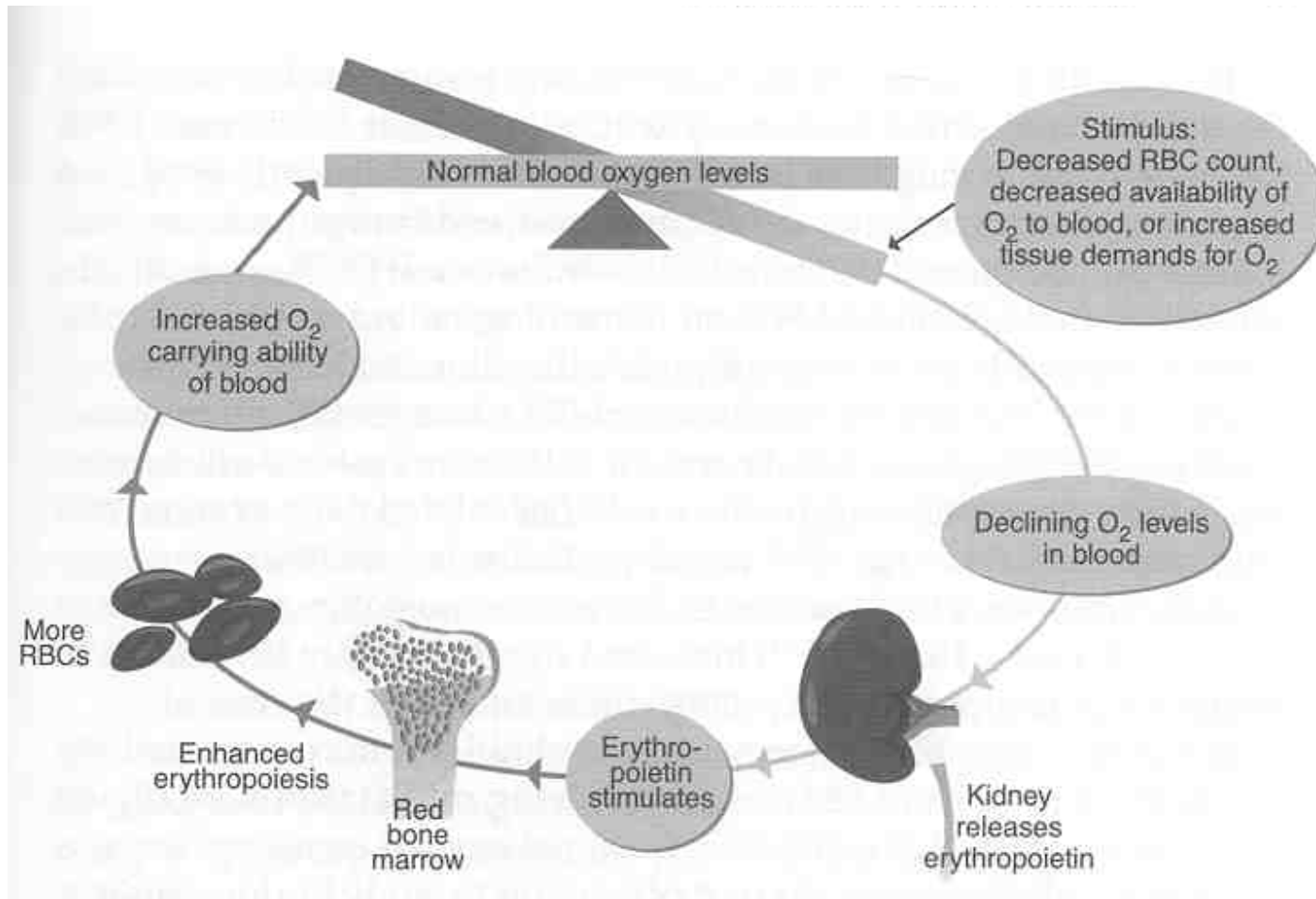
2) Live High – Train Low Altitude Training:

Effects on Hemoglobin Mass and Sea Level Performance

Key Question I for Elite Endurance Athletes:

How should i plan LHTL that hemoglobin mass increases?

Blood



Wilber, R. Altitude Training and Athletic Performance. Human Kinetics. 2004.



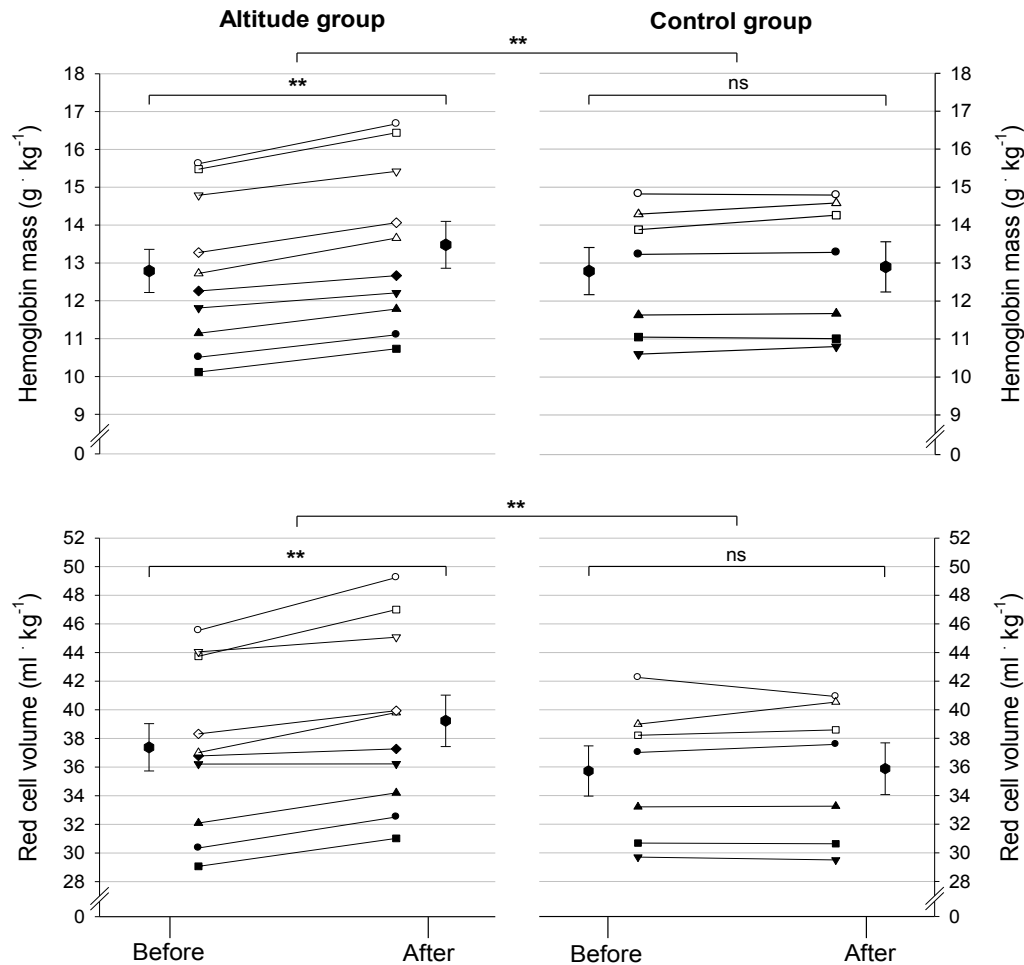
Blood – Situation when we started 10 years ago

Authors	Year	Altitude	Duration	Duration (h)	Technique	Result RCM / Hb _{mass}
Levine et al.	1991	2500	4 weeks	616	EB	↑ BV
Stray Gundersen et al.	1992	2500	4 weeks	616	EB	↑
Harper et al.	1995	2500	4 weeks	672	EB	↑
Levine et al.	1997	2500	4 weeks	616	EB	↑
Svedenhag at al.	1997	1900	4 weeks	720	I	→
Klausen et al.	1992	2000	6 days	144	CO	→
Friedmann et al.	1996	1800	3 weeks	504	CO	→
Telford et al.	1996	1760	4 weeks	672	CO	→
Gore et al.	1998	2690	4 weeks	744	CO	→
Ashenden et al.	1999	2650	12 days	207	CO	→
Ashenden et al.	1999	2650	2 weeks	108	CO	→
Ashenden et al.	2001	3000	4 weeks	207	CO	→
Dehnert et al.	2002	1956	2 weeks	182	CO	→

Adapted from Ashenden et al. 1999, Eur J Appl Physiol, 80:479-484



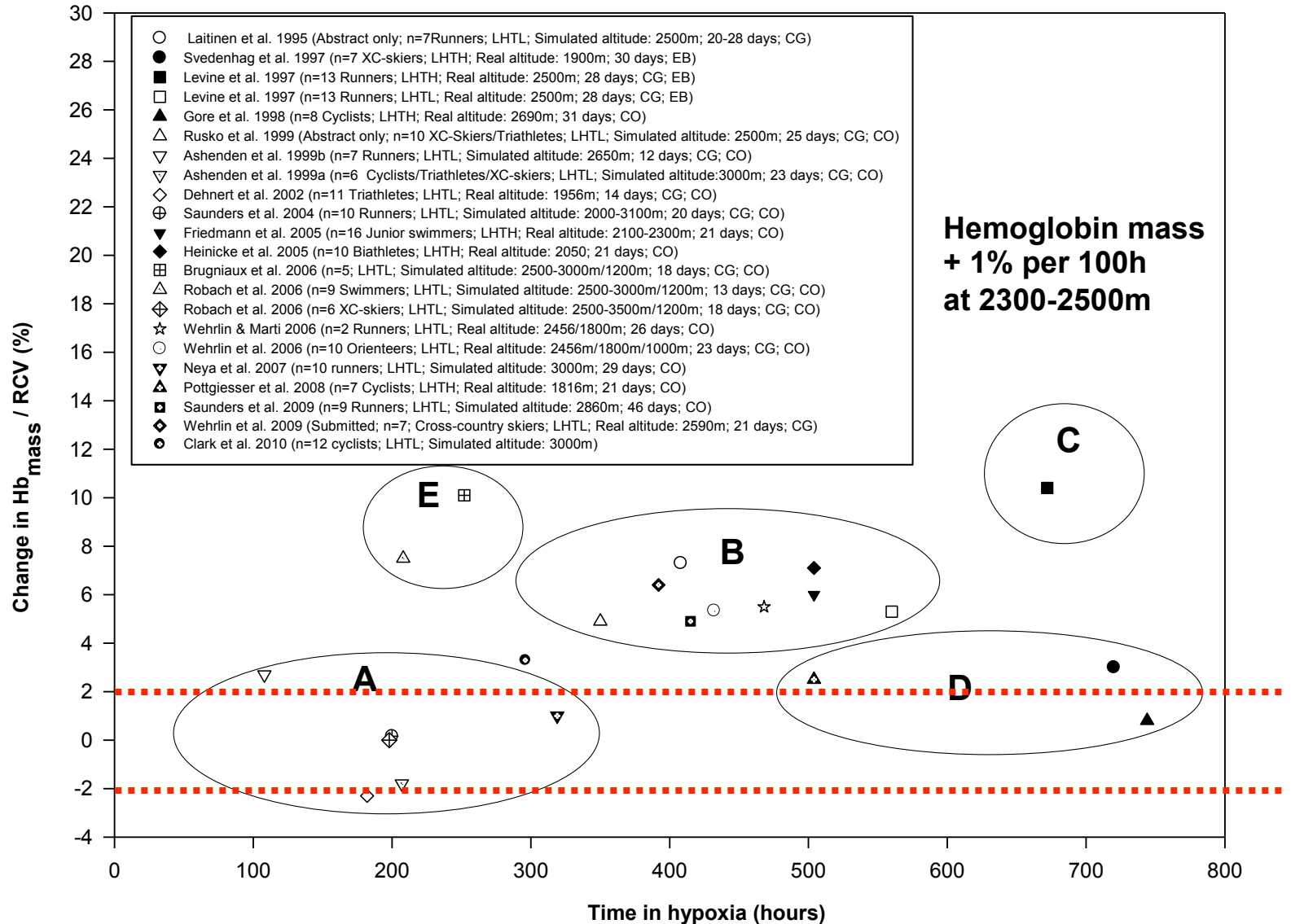
LHTL with CO Rebreathing and high enough hypoxic dose



Wehrli JP., Zuest P, Hallen J, Marti B, *J Appl Physiol*, 100: 1938-1945, 2006

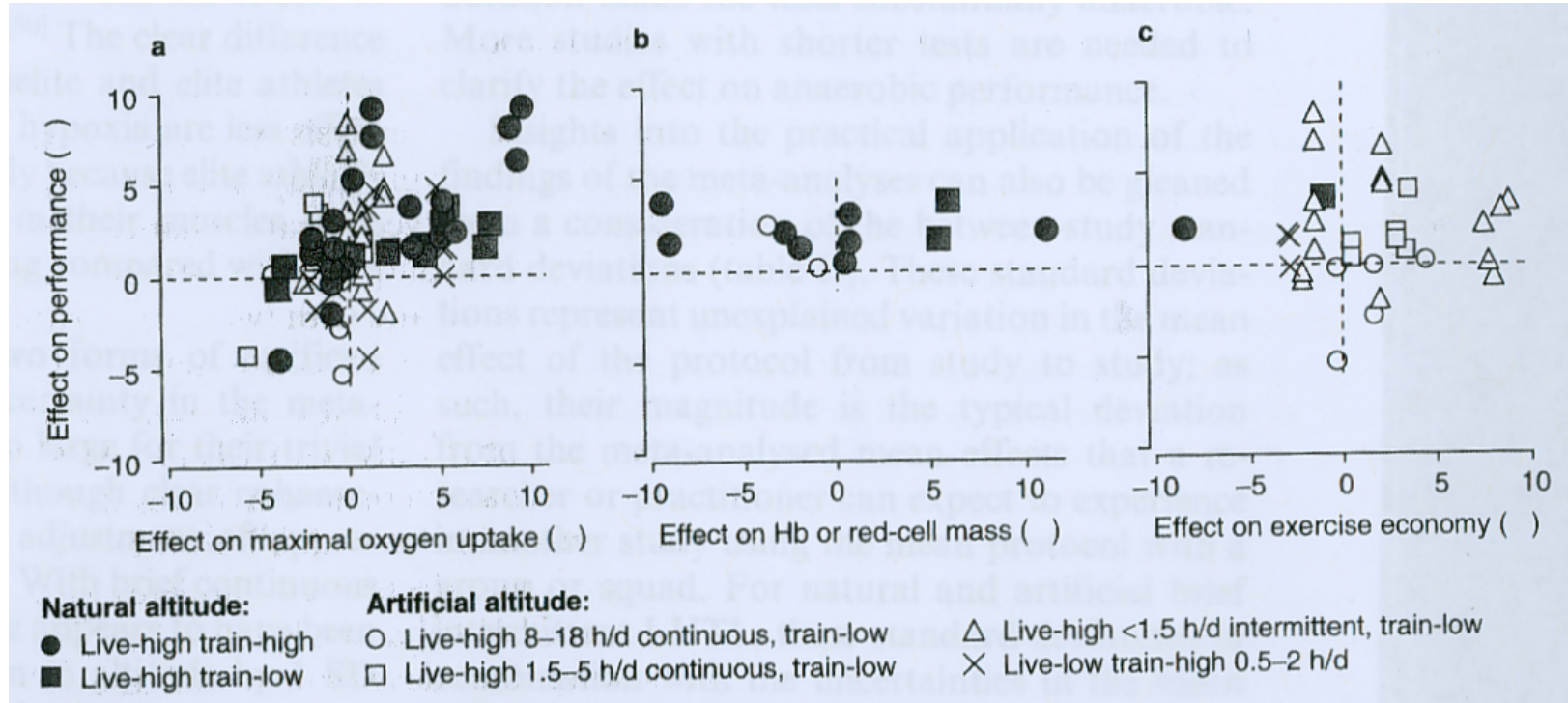


Live High – Train Low – Studies with CO Rebreathing Method





Blood & Performance



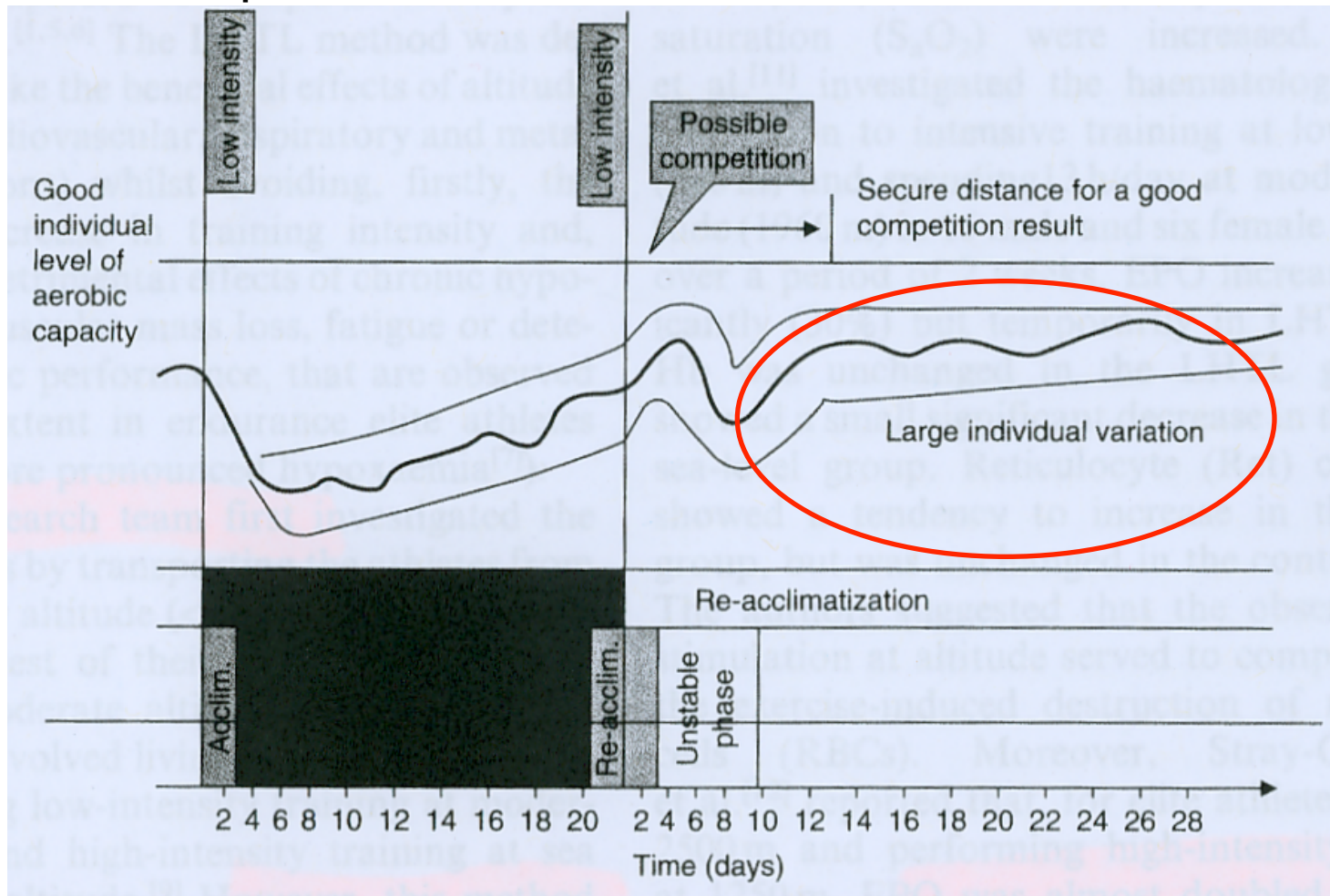
=> In summary, natural LHTL currently provides the best protocol for enhancing endurance performance in elite and subelite athletes

Bonetti & Hopkins, Sea level Exercise performance following adaptation to Hypoxia, Sports Med, 2009



3) Is performance after LHTL altitude training increased?

=> Keep in Mind:



Millet et al., Sports Med, 2010 (modified after Reiss)

3) Individual Hemoglobin Mass Responses

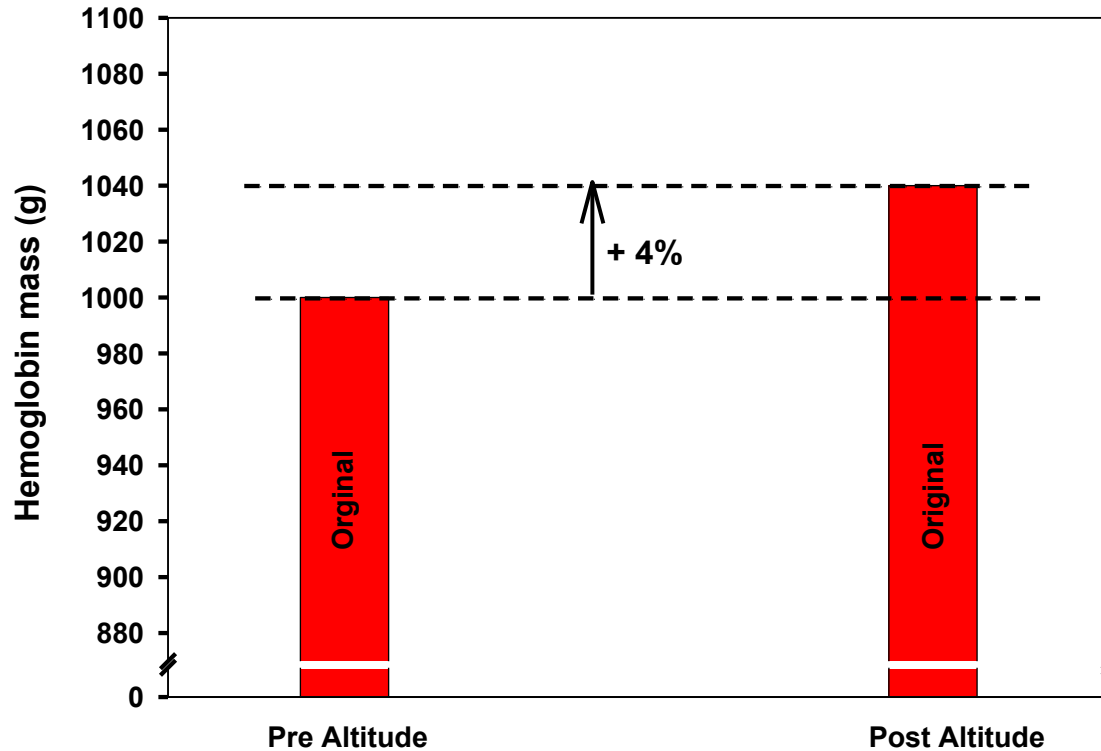
Key Question II for Elite Endurance Athletes:

Did **MY** Hemoglobin Mass increased with my LHTL Regimen?



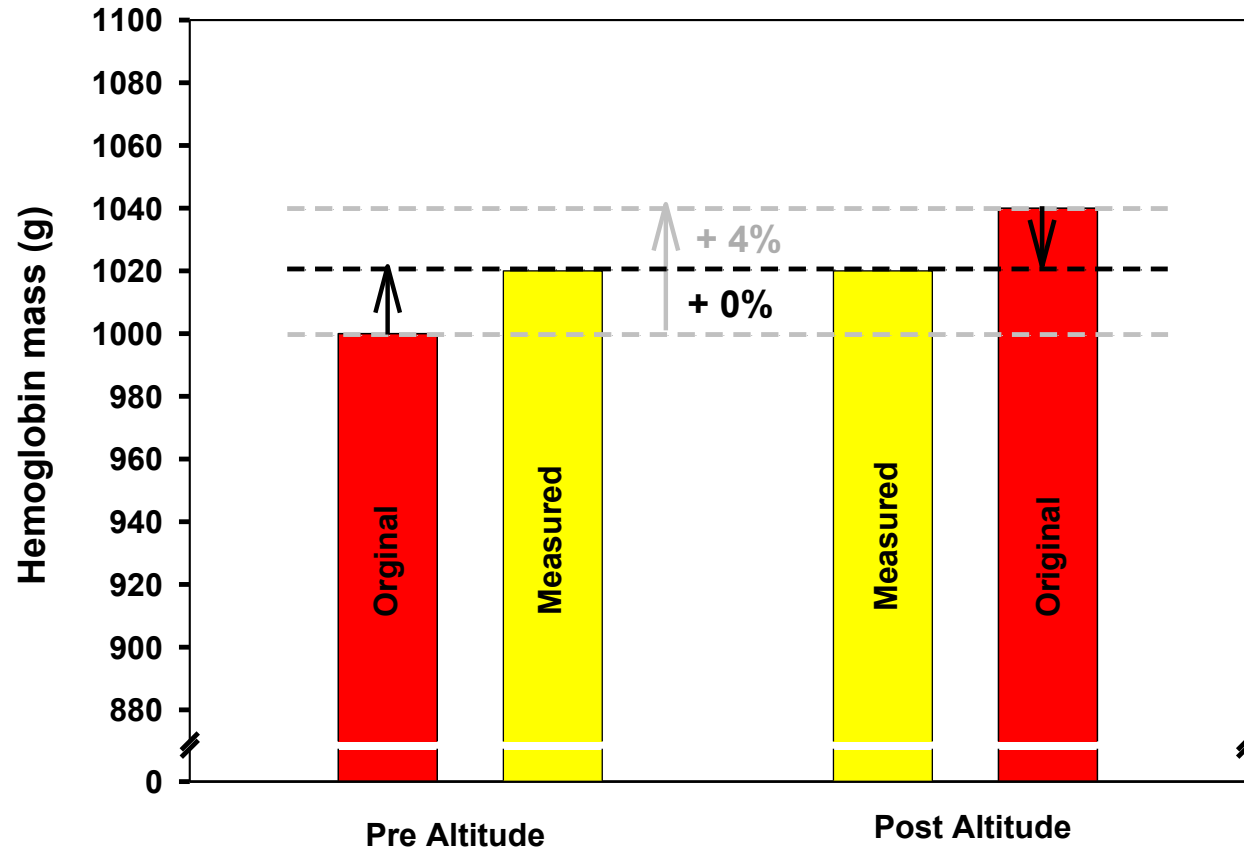
Individual Hemoglobin Mass Responses

Statistical Significance vs. Practical Relevance



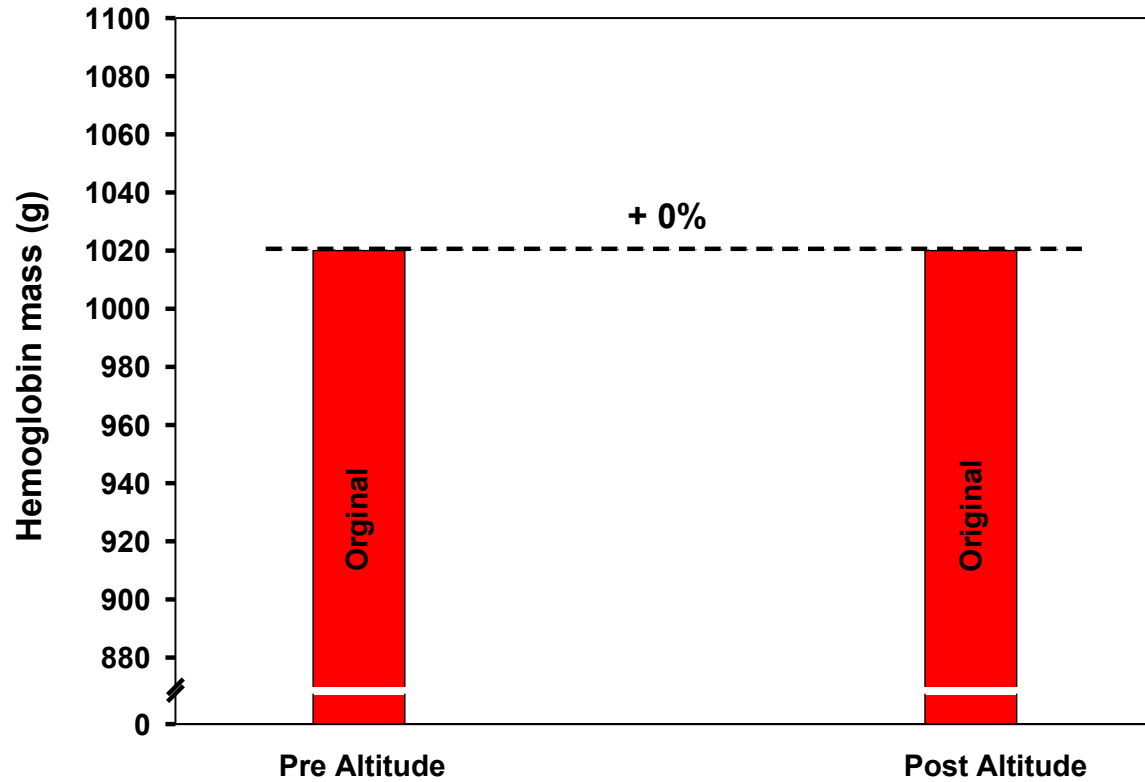


Individual Hemoglobin Mass Responses



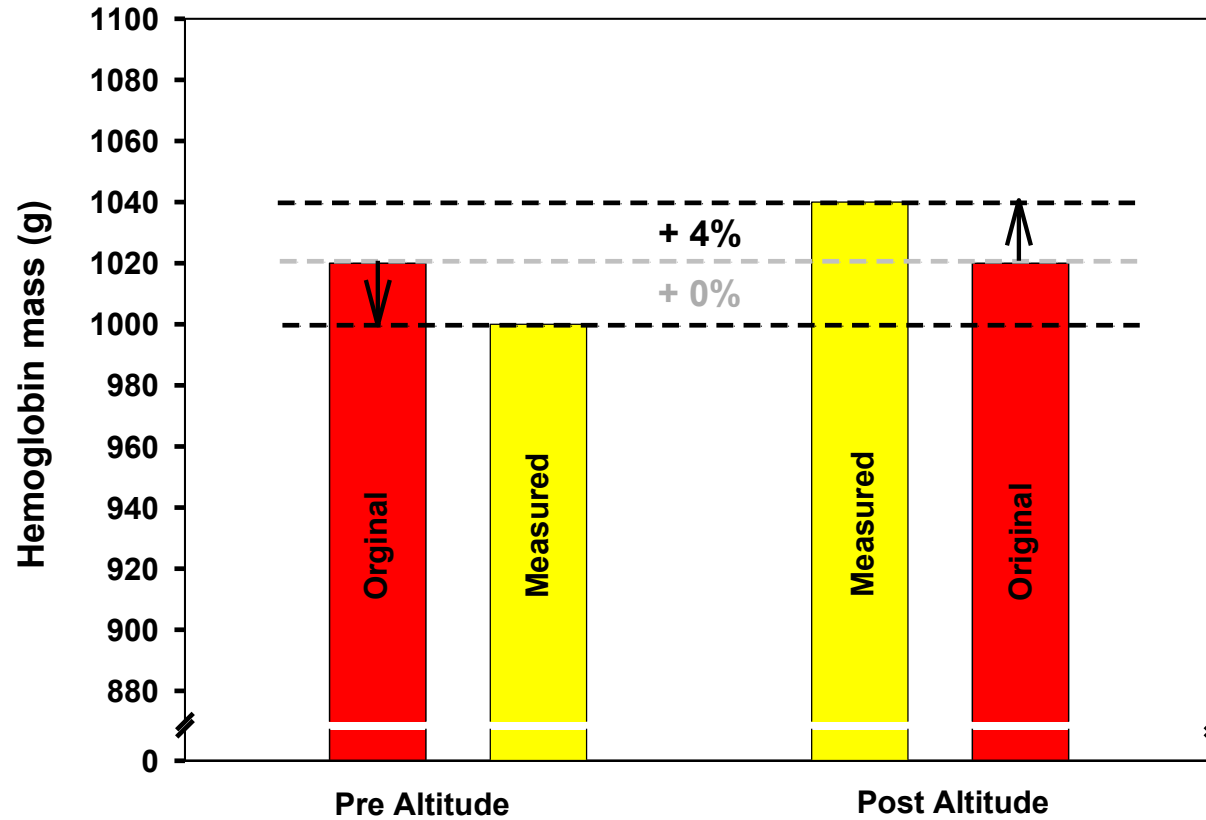


Individual Hemoglobin Mass Responses



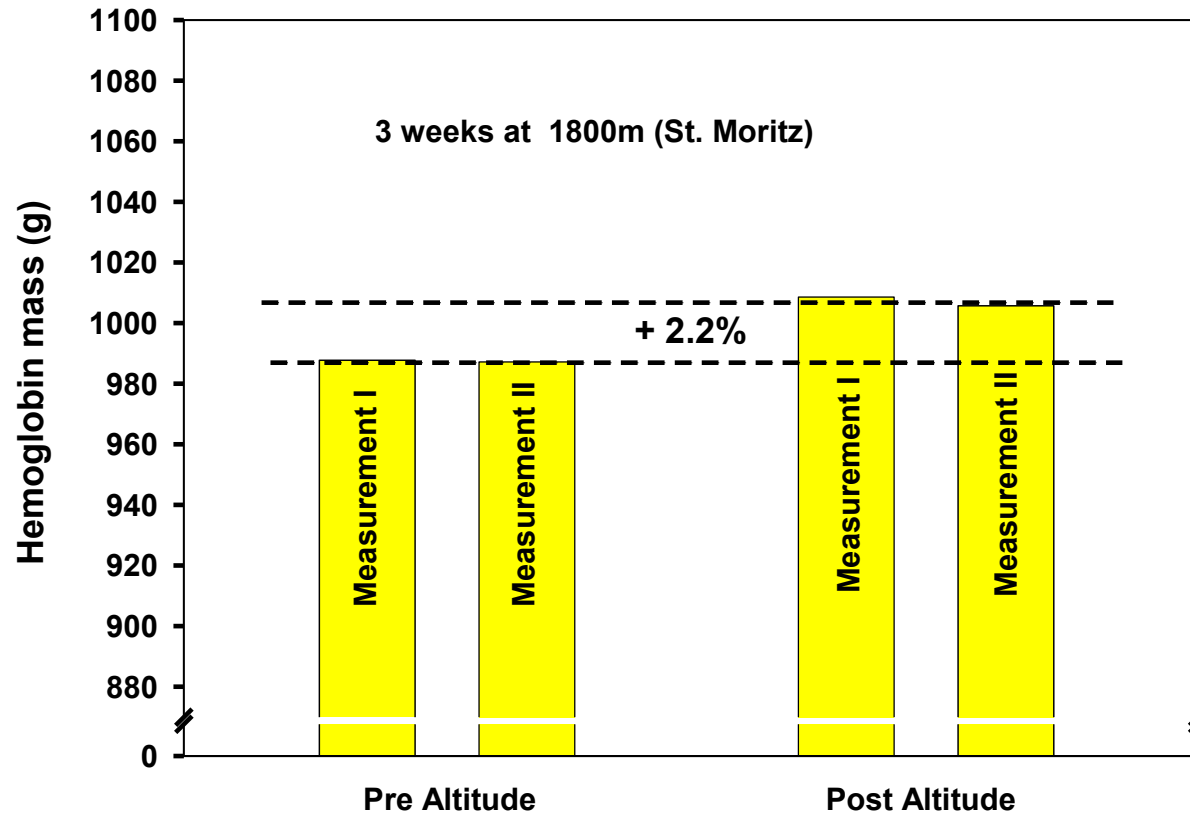


Individual Hemoglobin Mass Responses



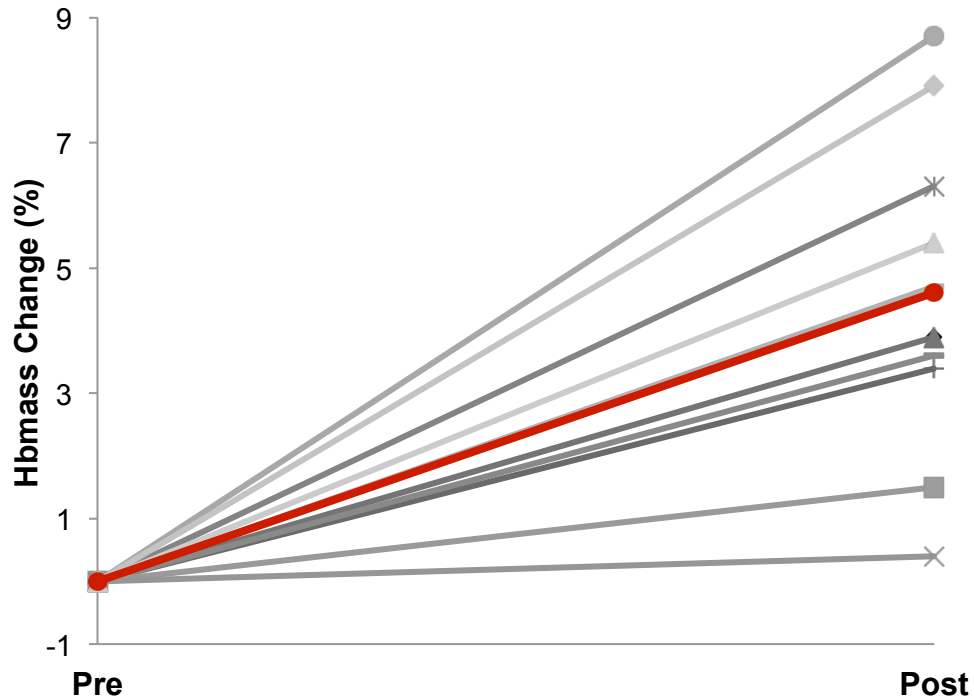


Double Hemoglobin Mass Measurements





Individual Hemoglobin Mass Response (LHTL)



Hauser et al. (In Preparation)



Anna Hauser
PhD Student
Magglingen –
Lausanne

4) Examples: Experiences with Swiss National Team Athletes





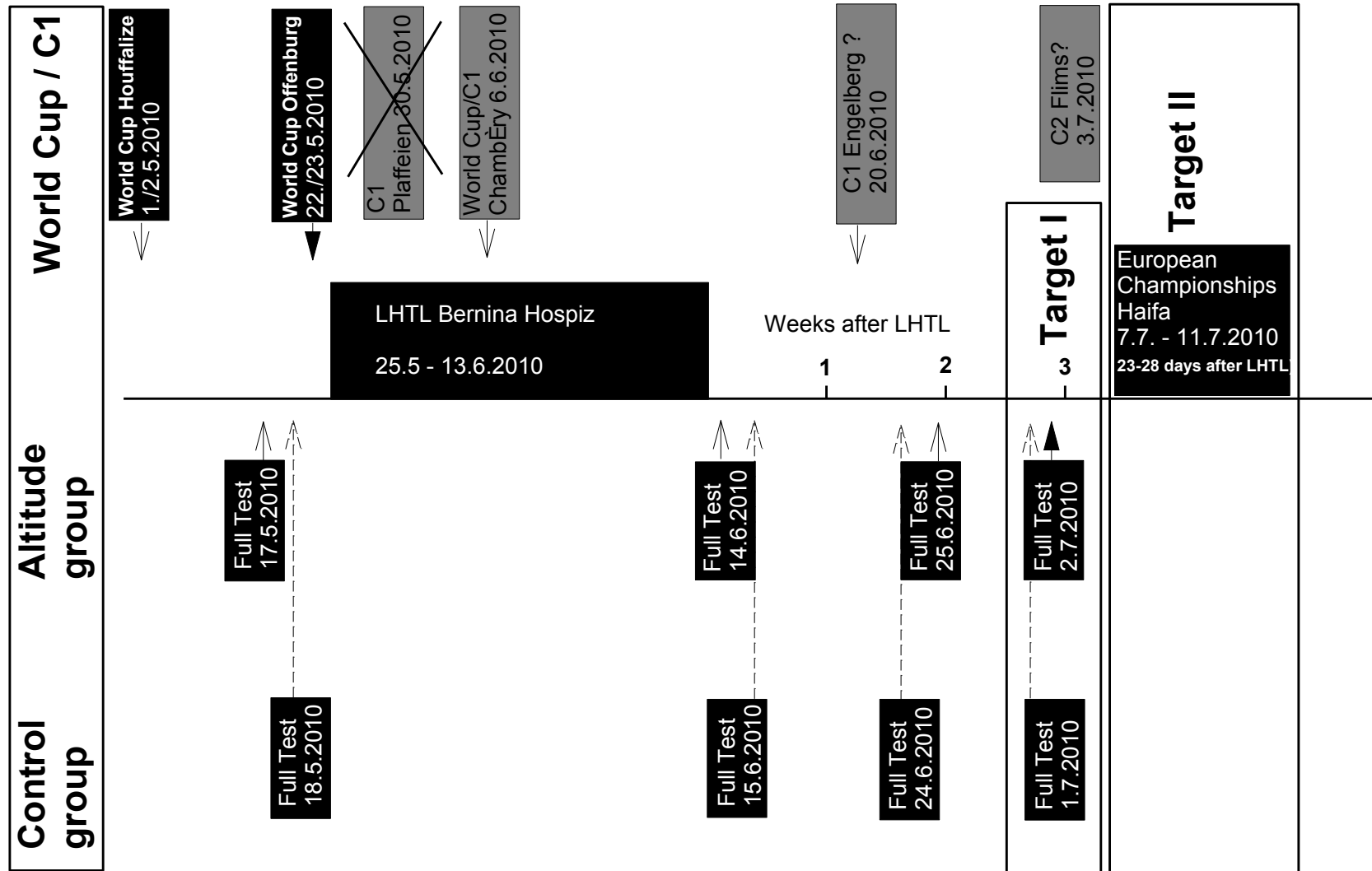
Example: Experiences with Swiss National Team Athletes



- 2010** **LHTL Altitude Training „Best Practice“**
- 2011** **Individual Adaptations**
- 2012** **London Olympic Games**

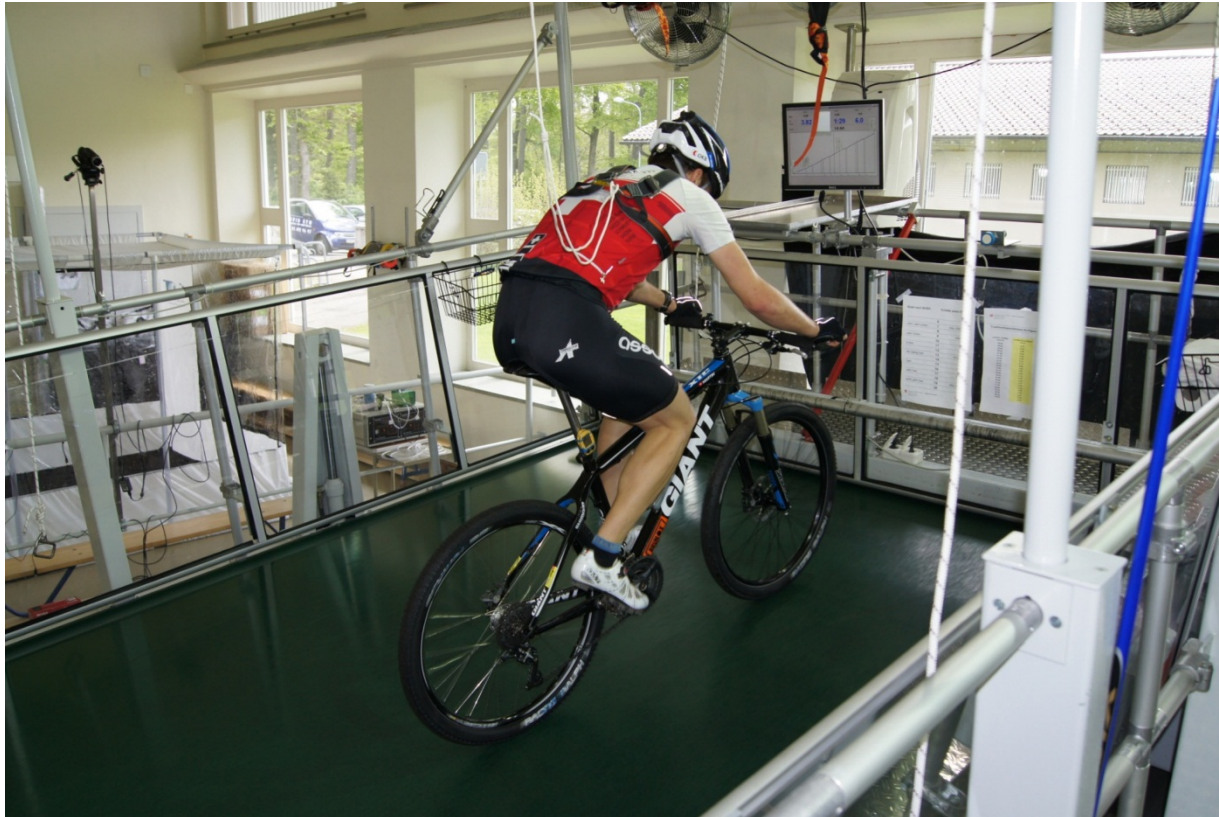


Example: Experiences with Swiss National Team Athletes





Example: Experiences with Swiss National Team Athletes



**Performance:
Capacity Test with
Self selected Speed**

+3.3%

(unpublished Data)

Example: Experiences with Swiss National Team Athletes



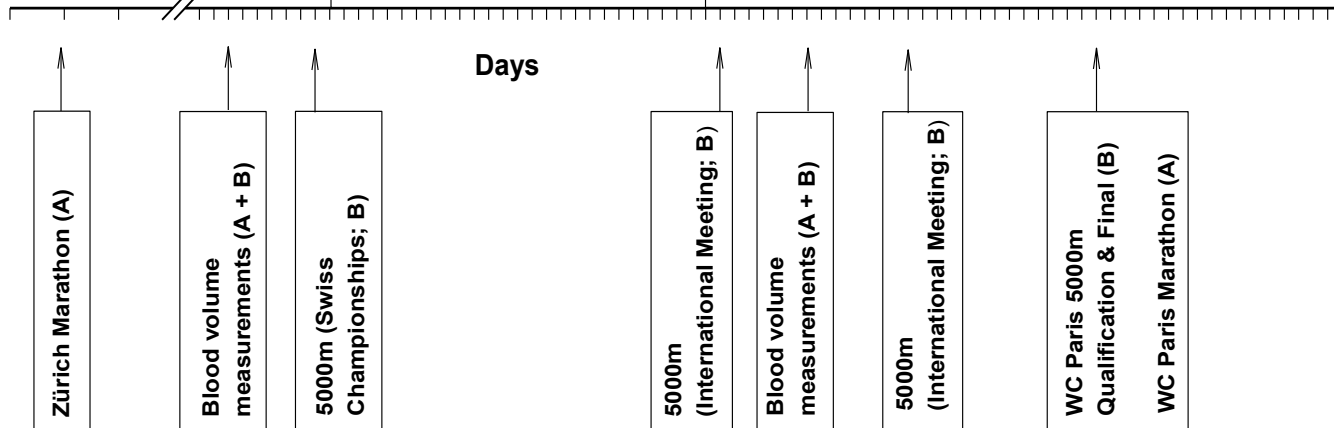
**Viktor Röthlin
Swiss Marathon**



Example: Experiences with Swiss National Team Athletes



Live high (2456m) and
train "low" (1800m) for 26 days



Wehrlin J, Marti, B.
Br J Sports
Med. (2006)



Example: Experiences with Swiss National Team Athletes

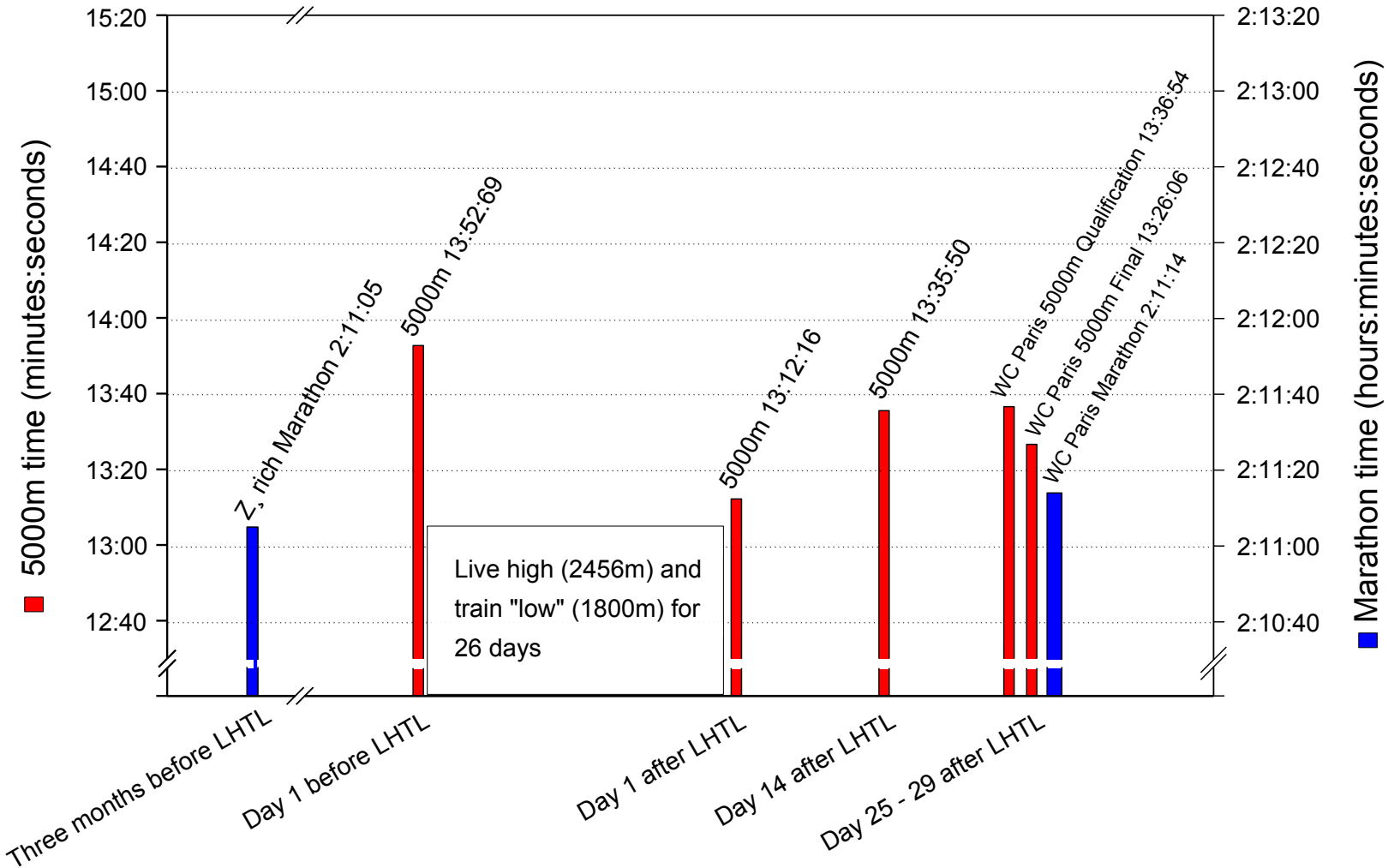
Table 1 Haematological variables before and after 26 days of living high and training low in two world class runners

	5000 m runner			Marathon runner		
	Before	After	% change	Before	After	% change
Packed cell volume	0.388	0.386	-0.5	0.427	0.438	+2.5
Haemoglobin (g/l)	132	133	-0.8	156	157	+0.6
Haemoglobin mass (g)	878	945	+7.6	952	988	+3.9
Erythrocyte volume (ml)	2581	2742	+6.3	2605	2757	+5.8
Plasma volume (ml)	4728	5064	+5.8	4099	4160	+3.9
Blood volume (ml)	7309	7807	+6.8	6704	6917	+3.2

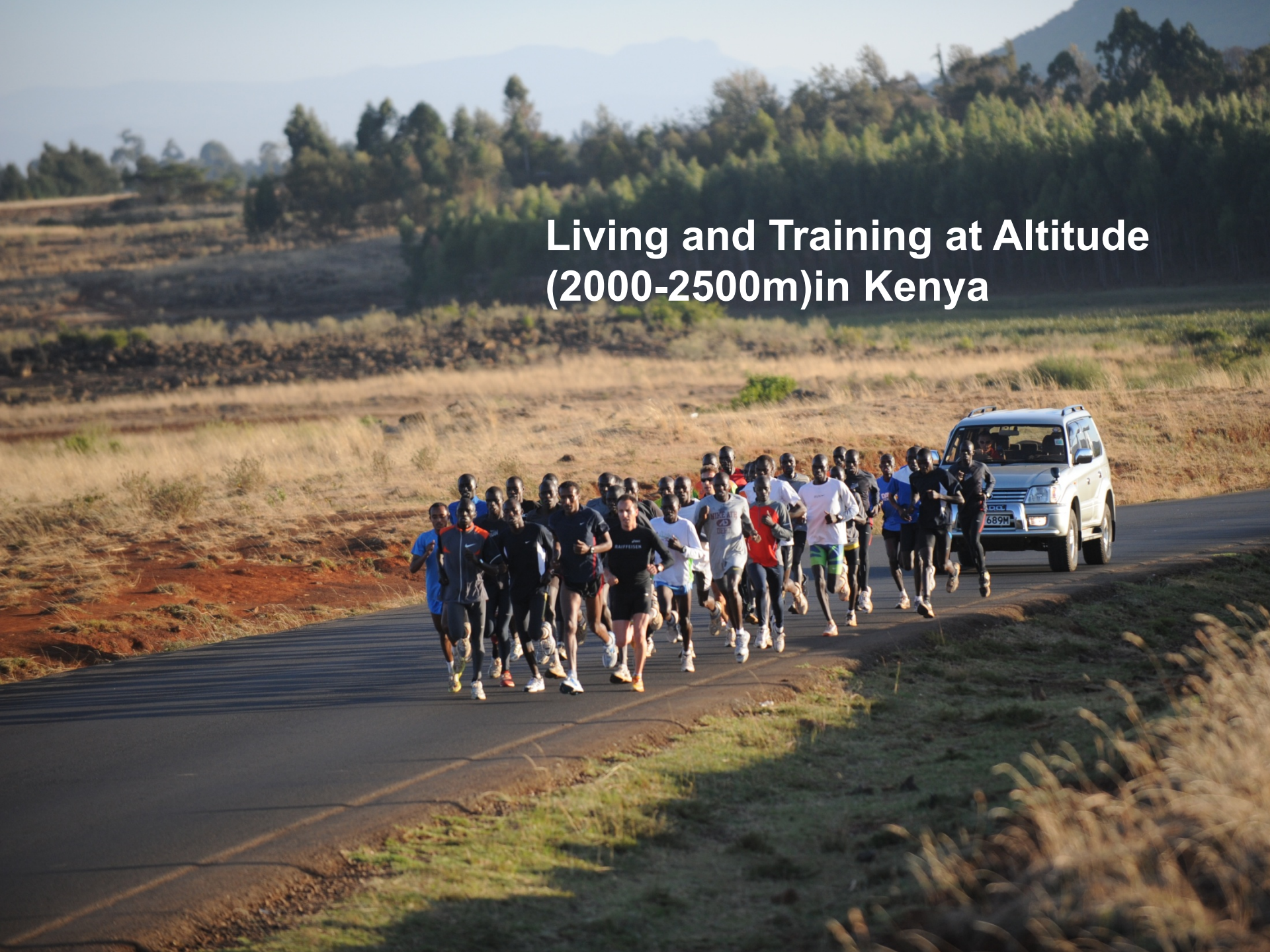
Wehrlin J, Marti, B. *Br J Sports Med.* (2006)



Example: Experiences with Swiss National Team Athletes



Living and Training at Altitude (2000-2500m) in Kenya





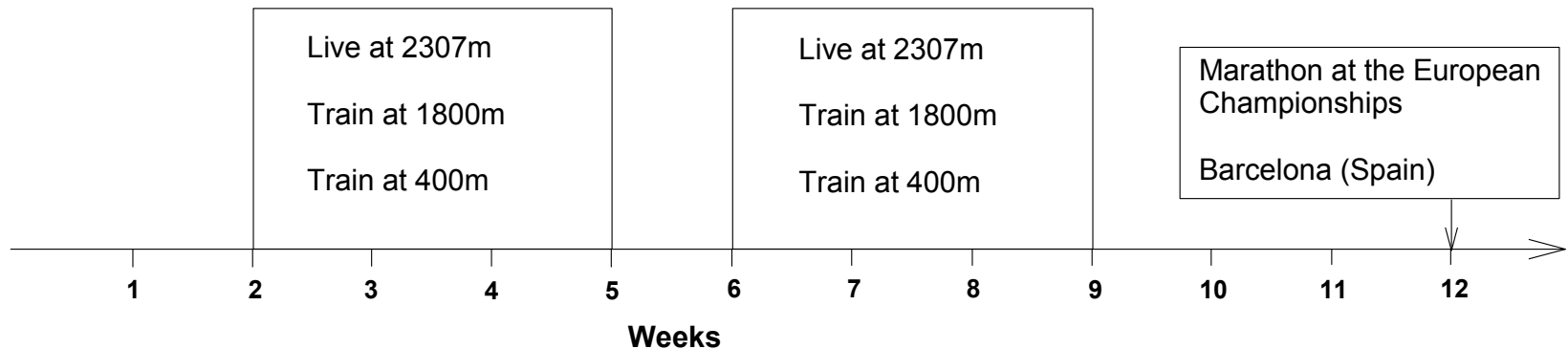
Beijing 2008

6. Place

***=>prepared with LHTL
altitude training***



2010: 1. Place, European Championships Barcelona





**Thank's for your
attention!**



Prix de Quervin 2014

Congratulations to Raphael Faiss!



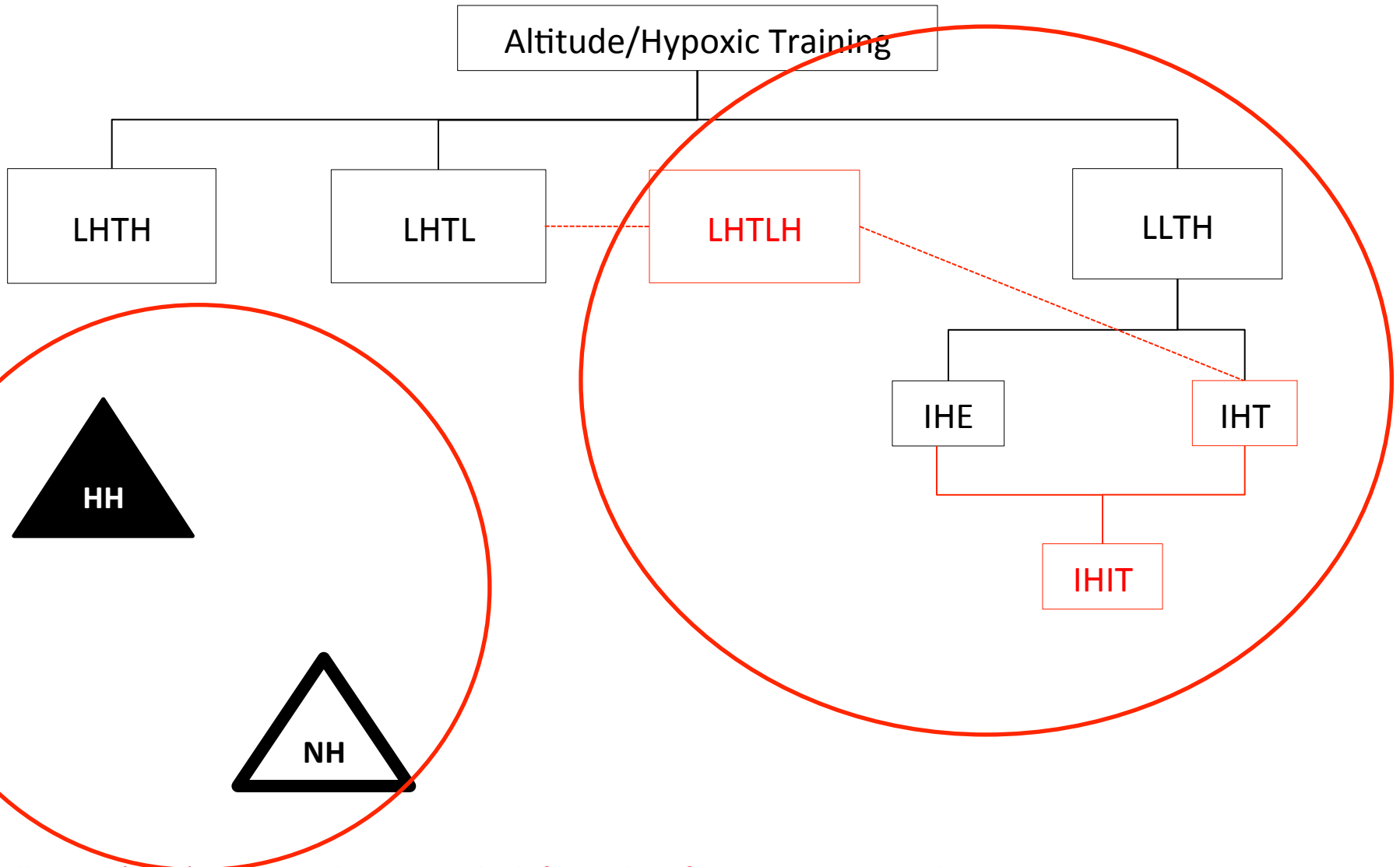
Congratulations to Grégoire Millet!



Thanks for excellent collaboration!



Panorama of altitude training strategies



Millet et al (2010) Combining hypoxic methods for peak performance. Sports Med

Wilber (2007) Application of altitude/hypoxic training by elite athletes. Med Sci Sports Exerc



Questions?